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# THE SHOCK AND VIBRATION DIGEST

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Code 5804, Naval Research Laboratory
Washington, D.C. 20375
(202) 767-2220

Dr. J. Gordan Showalter
Acting Director

Rudolph H. Volin

Jessica P. Hileman

Elizabeth A. McLaughlin

Mary K. Gobbett

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Dr. R.L. Eshleman
Vibration Institute
Suite 206, 101 West 55th Street
Clarendon Hills, Illinois 60514
(312) 654-2254

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# SVIC NOTES

*Personal Computers and Information Retrieval*

In most offices and many homes today you will find personal computers, word processors, and computer terminals. In the next few years, nearly every school and business will have access to these devices. This computerization of information storage and retrieval is the biggest change in the information dissemination business since Gutenberg printed a bible with movable type in the 15th Century. The book you are holding in your hands was printed using techniques that differ little from those used by Gutenberg 500 years ago.

In the past, computers were used mainly by businesses, academic, research, and government organizations. Today, things are different. Most of us now have access to these devices. With this accessibility, it is now possible for individuals to store and search data bases on their own personal computer or word processor.

What are the implications of this to publishers of current-awareness journals such as the Shock and Vibration Digest? Should information centers and publishers limit their information dissemination activities exclusively to 15th Century printing methods? Of course not! The question then is, "in what ways and how fast should the information dissemination business change?" My answer is that organizations should experiment a little and try new techniques in small pilot programs to see what works for them.

The following is a hypothetical example of one possible way to use the new technology to disseminate current awareness information. Titles and abstracts of technical papers could be sent to users on floppy magnetic disks. The information would be indexed by subject and author and would have to be compatible with a particular user's system. Users would put the disk into their system and search it themselves. Bibliographies on subjects such as the FINITE ELEMENT METHOD or ROTOR DYNAMICS could be printed out by users on their equipment. There are problems with this example, however. No software is available for small computers which has been written specifically for bibliographic information retrieval. There are, however, many database management programs available which can be used to store and retrieve bibliographic information. The other problem with setting up this hypothetical system is that with so many different computers and software packages available today, how does an information center decide which one to support? Supporting them all would be too costly.

Time may solve this dilemma. Today the bulk of the business-oriented personal computers are sold by just a handful of companies and to a lesser extent the same is true of data base management packages. If this trend continues, it could happen that an information center could support most of its users by supplying floppy disks compatible with only a half dozen computer systems.

*This one example was chosen to illustrate a point; there are many other possibilities such as electronic mail, teleconferencing, etc.,* which should also be considered. I urge all of you to try out some of the new methods. The sooner you do, the quicker your organization will reap the possible benefits of these new techniques.

J.G.S.

# EDITORS RATTLE SPACE

## ON THE AVAILABILITY OF ACCEPTABLE VIBRATION LEVELS

One of the most frequent questions asked by field engineers has to do with the acceptable vibration level of a particular machine. Engineers are interested in normal machine vibration levels, but they are most concerned with unusually high vibrations that are about to shut down production. At this point the question of acceptability becomes very important. Unfortunately, there are no books, charts, or tables to tell the engineer what is tolerable. And many times unnecessary production losses occur or a machine is wrecked because intolerable levels are attained.

Various tables and charts are available that do provide acceptable vibration levels for operating machinery; however, they are concerned with general machinery. Charts that provide data for specific machine types and bearing configurations must be considered guidelines rather than specific levels. Every machine has its own spring-mass-damping characteristics and will therefore have its own acceptable vibration level. Even machines of the same design can have different bearing or seal clearances that provide different acceptable vibration levels. What is the answer to this dilemma?

General vibration criteria of today can be used as guidelines; however, the engineer must know details of a machine's design as well as its dynamic behavior during the various types of excitation that arise from defects and adverse operating conditons. Detailed knowledge of a machine can be obtained from rotor-dynamic measurements and calculations. Bearing forces and clearances, rotor stresses, coupling forces, and rotor-casing interferences can be assessed using rotor simulation and confirmed with measurements. Knowledge of a machine obtained prior to a crisis prepares the engineer for a problem when it arises and enables him to make a competent decision on whether or not to shut down.

Unique work* on acceptable levels of relative journal bearing vibration has recently been published. Dynamic characteristics, fatigue strength, and clearances of bearings are used to assess acceptable vibration levels. The method can be applied on an individual basis to any operating machine in which fluid-film bearings are used. The method does not assess the severity of any rotor-dynamics problem but does give a detailed picture of bearing operation.

Thus, acceptable machine vibration levels can be obtained only on an individual basis, and, due to the unique nature of machine designs, this fact of life will remain with us. However, means are available to determine acceptable levels through rotor-dynamic studies. If a machine is important enough to ask the question -- is this level of vibration acceptable -- then acceptable vibration levels should be determined on an individual basis.

R.L.E.

***McHugh, J.D., "Estimating Allowable Shaft Vibration Limits for Fluid Film Journal Bearings," Proc. of Machinery Vibration Monitoring and Analysis Meeting, New Orleans, LA, 1982, Vibration Institute, Clarendon Hills, IL.***

# TECHNIQUES FOR NONLINEAR RANDOM VIBRATION PROBLEMS

J.B. Roberts*

***Abstract.*** *This review discusses methods for solving nonlinear stochastic problems in dynamics that have been proposed in papers published during the last three years. Emphasis is placed on the application of these methods in engineering applications.*

The problem of predicting the response of a mechanical system to random excitation occurs in many fields of engineering; an excellent survey has been published recently [1]. Thus, studies of the responses of buildings to earthquakes and wind forces, of aircraft and missile structures to atmospheric turbulence and acoustic excitation, of ships and offshore structures to wave forces, and of land vehicles to surface roughness, all involve modeling the excitation as a random process and predicting the characteristic features of the corresponding response process. In these applications of stochastic process theory a linear model of the system can be sufficient for some purposes; standard linear theory, which can be found in a number of textbooks [2-8], can then be applied. However, frequently the possibility of the response reaching large and potentially dangerous amplitudes is of greatest interest. For large amplitude motion, nonlinearities in the system are often critically important because they significantly influence the tails of response probability distributions. Methods for studying nonlinear effects in random vibration problems are thus of considerable practical importance, and they have received much attention in the literature.

A difficulty with the literature on nonlinear random vibration is that it is widely scattered in many scientific journals, conference proceedin's, and reports and is thus not easily accessible. For this reason a survey was undertaken three years ago by the present author in an attempt to provide a coherent view of the main theoretical techniques that are available [9-10]. A review of the particular method known as stochastic (or equivalent) linearization was undertaken by Spanos [11] at about the same time. In addition, a number of earlier reviews [12-19], other references [9-11], and a monograph by Dimentberg [20] provide a good picture of progress in the area up to 1980.

The present review discusses work that has been published during the last three years. It is evident from the histogram shown in the figure, which is based on papers cited in this review, and in certain other work [9, 10], that nonlinear random vibration is still in a very active state of development!

## THE FPK METHOD

The excitation processes of nonlinear systems excited by wide-band random processes can usually be modeled as white noise. It follows from this idealization that the state vector, which contains the displacements and velocities, is a Markov process with a transition density function governed by a diffusion equation known as the Fokker-Planck-Kolmogorov (FPK) equation [9].

***Exact solutions.*** Exact solutions of the FPK equation can be found only in special cases, which usually relate to the steady-state response to stationary excitation. For second order systems driven by white noise a general form of the equation of motion is

$$\ddot{x} + g(x,\dot{x}) = \xi(t) \tag{1}$$

where g is some function of the displacement x and velocity $\dot{x}$, and $\xi(t)$ is a white noise process. Caughey and Ma [21] have recently shown that an exact, steady-state solution is possible if g can be written as

$$g = (H_y\, f(H) - H_{yy}/H_y)D\dot{x} + H_x/H_y \tag{2}$$

*School of Engineering and Applied Sciences, University of Sussex, Falmer, Brighton, Sussex, England, BN1 9QT

where $y = \dot{x}^2/2$ and $H(x, y)$ is the energy integral of the conservative oscillator

$$\ddot{x} + H_x/H_y = 0 \tag{3}$$

Here

$$H_x = \frac{\partial H}{\partial x}, \; H_y = \frac{\partial H}{\partial y}, \; H_{yy} = \frac{\partial^2 H}{\partial y^2} \tag{4}$$

and D is related to the strength of the white noise process; i.e., $E[\xi(t)\xi(t+\tau)] = 2D\delta(\tau)$. The steady-state joint density function for x and $\dot{x}$ is then

$$p(x,\dot{x}) = C \exp \{- \int_0^H f(\xi)\, d\xi\} H_y \tag{5}$$

where C is a normalization constant [21]. This result can be regarded as an extension of an earlier result for the case in which $H_y = 1$ as has been described [9]. Caughey and Ma [21] indicated generalizations of their solution to a class of nonlinear complex systems and provided specific examples. Related, exact solutions for certain classes of multi-degree-of-freedom nonlinear systems have also been given by Caughey and Ma [22] and Dimentberg [23]. Certain exact solutions [21-23] appear to be the most general available thus far for non-parametrically excited nonlinear systems.

Dimentberg [24] has obtained an exact steady-state solution for a second order system with combined parametric and external excitation. An equation of motion of the form

$$\ddot{x} + 2\alpha\dot{x}[1 + \eta(t)] + \beta\dot{x}(x^2+\dot{x}^2/\Omega^2) + \Omega^2 x[1 + \zeta(t)] = \xi(t) \tag{6}$$

is considered; $\eta(t)$, $\zeta(t)$, and $\xi(t)$ are independent white noises, and $\alpha$, $\beta$, and $\Omega$ are constants ($\beta \geqslant 0$). An additional assumption is required; i.e., that the noise intensities of $\eta(t)$ and $\zeta(t)$ satisfy certain conditions. The relationship between the exact result for the system of equation (6) and the corresponding result obtained by the method of stochastic averaging is explored; use of the exact result in establishing stability criteria is discussed. It is noted that, for the case of purely external excitation -- i.e., $\eta(t) = \zeta(t) = 0$ -- equation (6) is of the general form of equation (1) in which

$$g = 2(\beta\Omega^{-2}H + \alpha)\dot{x} + \Omega^2 x \tag{7}$$

This is a special case of equation (2); $H_y = 1$, $f(H) = 2(\beta\Omega^{-2}H+\alpha)/D$.

***Approximate numerical solutions.*** Series solutions to FPK equations can be found in terms of eigenfunctions, but in only a few cases can these be found analytically [9]. Johnson and Scott [25, 26] have studied specific first and second order nonlinear systems using this approach. The first order system they considered was governed by the equation

$$\dot{x} + x + \varepsilon x^3 = \xi(t) \tag{8}$$

where $\epsilon$ is a small parameter. The eigenfunctions can be found exactly if $\epsilon = 0$; a perturbation series can thus be developed for the nonlinear case in which $\epsilon$ is small but finite. It has been shown [25] that convergence problems associated with perturbation series can be overcome by a combination of numerical and analytical techniques. A similar approach has been used [26] to obtain results for the second order system described by

$$\ddot{x} + \beta\dot{x} + x + \varepsilon x^3 = \xi(t) \tag{9}$$

$\beta$ is a constant and $\epsilon$ is small.

Alternative approaches to the numerical solution of FPK equations have been discussed recently by Dao and Anh [27], who refer to a number of recent papers in Vietnamese journals, and by Fijita and Hattori [28]. In the latter paper the FPK method was used to study the statistics of an oscillator interacting with two elastically supported reflectors. The time-dependent joint distribution of displacement and velocity was determined approximately by assuming a form for this distribution with three unknown functions of time that are determined by the method of weighted residuals. Good agreement was obtained with experimental results, as in the stationary case [29].

***Stochastic averaging (STAV).*** For lightly-damped nonlinear oscillators responding to wide-band excitation the response is narrow band in character. The method of stochastic averaging (STAV), due to Stratonovitch [30], can be used in these circumstances to generate relatively simple approximate solutions. The application of STAV generally involves obtaining an FPK equation for the amplitude envelope A(t) of the response process; this process is uncoupled from the corresponding phase process [9]. Thus, for a second order system the FPK equation for A(t) is of first order and can be solved fairly readily.

There has been recent interest in applying STAV to systems driven by nonstationary excitation. The time-dependent solution to the FPK equation for A(t) must be found. The case of nonlinear oscillators excited by a suddenly applied, stationary input has been discussed [31]; numerical results for the transient response were obtained by approximating A(t) as a discrete random walk process. This is equivalent to replacing the FPK equation for A(t) by a finite-difference approximation. Good agreement was obtained between results from STAV and corresponding digital simulation estimates. A more general class of nonstationary input has been considered by Spanos [32-34]; a broad-based stationary process was modulated by a slowly varying deterministic function. The time-dependent solution of the FPK equation for A(t) was found approximately using a Galerkin technique. Good agreement with digital simulation results was again obtained.

STAV also offers a powerful method for attacking the first-passage problem; i.e., the problem of finding the probability that the response process stays within specified limits over a prescribed interval of time [35-36]. Spanos [37] has recently obtained some results for the first passage time of a lightly-damped nonlinear oscillator excited by a stationary process; he used a Galerkin technique to solve the backward Kolmogorov equation associated with the FPK equation for A(t).

In a number of recent papers STAV has been used to study the response of offshore structures and ships to irregular waves [38-48]. In these applications the predominant nonlinearity often arises from hydrodynamic damping, which tends to be quadratic in nature; STAV is particularly effective in dealing with this type of nonlinearity provided the damping is light. Brouwers [36] has related STAV to a method involving two-scale expansions and to the method of equivalent linearization. He compared numerical, time-domain, simulation results with STAV and showed that STAV can be used successfully to predict the response distribution of a marine riser in random waves. Both quadratic hydrodynamic damping and Coulomb frictional damping were incorporated into the mathematical model. It has been shown [36] that Colomb friction can be a significant source of nonlinearity in marine riser systems. The application of STAV to offshore, space-frame jacket structures responding to random waves has been considered [39]. Morison's equation was used to obtain a nonlinear relationship between the loading on the structural elements and the wave motion; some numerical results were presented for a typical structure. The significance of the non-Gaussian nature of the response on fatigue life estimation has been pointed out [40]; some comparisons were made with corresponding numerical results obtained from a perturbation analysis.

It has recently been demonstrated that STAV is a useful method for studying the rolling motion of ships and transport barges in irregular seas [41-48]. The probability of the roll amplitude reaching dangerous levels is of primary interest, and STAV offers an approximate analytical approach to estimating this quantity. It was demonstrated [41, 43, 44] in a comparison with digital simulation results that STAV can give useful statistical information on roll response, damping values, and excitation spectral bandwidths that are typical of those encountered in practice. Moreover, good agreement has been obtained between predictions from STAV and experimental results obtained from a model ship rolling in irregular beam waves in a wave tank [45]. A particular advantage of the STAV technique is that it can be used to investigate possible instabilities arising from parametric terms in the equations of motion [42, 46-48].

***Generalizations of stochastic averaging.*** The standard STAV method is applicable only to systems in which the restoring forces are weakly nonlinear. Consider the following specific equation of motion for a nonlinear oscillator

$$\ddot{x} + \varepsilon^2 f(x,\dot{x}) + G(x) = \varepsilon\, y(t) \qquad (10)$$

G(x) is an arbitrary nonlinear restoring function and y(t) is the excitation process; $\epsilon$ is a scaling parameter, which is small, and the excitation is scaled so that the standard deviation of x of order $\epsilon^0$. If G(x) is almost linear, such that

$$G(x) = \omega_o^2 x + \varepsilon^2 h(x) \qquad (11)$$

it follows that the amplitude process

$$A(t) = \left[x^2 + \dot{x}^2/\omega_o^2\right] \qquad (12)$$

varies slowly with time when $\epsilon$ is small. Application of the STAV method shows that, in these circumstances, A(t) converges (weakly) to a Markov process as $\epsilon \rightarrow 0$, and an appropriate FPK equation for A(t) can be derived [9]. In fact, the nonlinear restoring term h(x) does not contribute to the drift and diffusion coefficients in this FPK equation; the effect of this term is of higher order than the effect due to the damping term.

Thus, the standard STAV method is ineffective in dealing with the effect of nonlinearities in the restoring moment. This difficulty can be overcome by a suitable generalization of the STAV method. If, for the system of equation (10), G(x) is strongly nonlinear, the energy envelope process

$$E(t) = \frac{\dot{x}^2}{2} + \int_0^x G(\xi)\, d\xi \qquad (13)$$

is slowly varying with respect to time. Stratonovitch [30] and Roberts [9] have shown that E(t) converges to a Markov process as $\epsilon \rightarrow 0$. From the FPK equation for E(t) can be derived an expression for the joint distribution of x and $\dot{x}$ from which many important statistical parameters of the response process can be computed.

It has recently been shown by Zhu [49, 50] that a theorem due to Khasminskii [51] can be used to provide a rigorous mathematical basis for the generalized stochastic averaged method applied to the energy envelope E(t). Thus, earlier physical arguments by Stratonovitch [30] and Roberts [52] can be justified. Moreover, Zhu has shown that this method can also be applied when the equation of motion contains parametric terms. Specifically, Zhu considers the equation of motion of a nonlinear oscillator of the form

$$\ddot{x} + \epsilon^2 f(x,\dot{x}) + G(x) = \epsilon \sum_{i=1}^{n} \lambda_i(x,\dot{x})\xi_i(t) \qquad (14)$$

$\xi_i(t)$ are white noises. He obtained an FPK equation for E(t) and considered a number of specific examples in detail; the energy envelope method was used to formulate stability criteria.

A particular case of equation (14) was also studied earlier by Dimentberg [20, 53] using the same approach; he treated in some detail a system with linear damping and cubically nonlinear stiffness that was simultaneously excited by external and parametric random excitation. He obtained good agreement with digital simulation estimates.

Some further analytical results derived from the energy envelope method have been given recently by Spanos [32]. He considered the case of a nonlinear oscillator driven by a broadband, nonstationary random process and showed that an exact solution of the FPK equation for E(t) is possible if the nonlinear stiffness is of a power-law form and damping is linear. This generalizes a result found earlier for the transient response to suddenly applied stationary random excitation [31].

In principle, for a system governed by equation (10) the energy envelope process E(t) should converge to a Markov process, as $\epsilon \pm 0$, irrespective of the shape of the input spectrum. It should thus be possible to derive an FPK equation for E(t) that is valid for nonwhite excitation; i.e., takes into account the shape of the input spectrum. Such a generalized FPK equation has been derived [54] using physically based arguments [41]. Results from this theory are found to agree favorably with digital simulation estimates for the specific case of a Duffing oscillator with linear damping [54]. The use of the energy envelope method for nonwhite excitation has also recently been suggested by Zhu [50].

An alternative approach to dealing with nonlinear systems driven by nonwhite excitation involves the construction of a filter that will generate the excitation process from white noise. The combined filter-plus-system can then be analyzed by the FPK method. A major difficulty with this approach is that the dimensionality of the FPK equation is increased by the addition of a filter; this in turn considerably increases the difficulties associated with obtaining solutions to the equation. Davies [55] has recently employed this approach to study a second order system driven by a first-order excitation process. The filter is of a first order, so that the complete filter-plus-system is of third order. If it is assumed that damping is light, the appropriate FPK equation is approximated, and an exact solution can be found to this approximated relationship. Davies proposed a method for extending the validity of the solution to larger values of damping and presented results for the distributions of maxima in the system response.

It is possible to generalize the standard STAV method in another direction by introducing higher order approximations; i.e., terms of higher order in $\epsilon$. An iterative procedure for computing such approximations [30] has recently been applied to the study of a second order system with combined white noise forced and parametric excitation [56] and to two-degree-of-freedom systems with auto-parametric coupling [57].

## EQUIVALENT LINEARIZATION

The FPK method has the great advantage that it gives information on the distribution of response variables; this advantage is offset by the fact that the range of problems that can be solved is limited. For more difficult problems that cannot be tackled by the FPK method, the technique of equivalent linearization (EL) is extremely useful. An equivalent linear equation of motion can be obtained from the nonlinear equation by minimizing the difference between the two equations in a least square sense [10]. Although EL cannot yield information on the effect of nonlinearities on the distribution of the response, it is a very powerful and flexible method for predicting the mean square response of complex nonlinear systems to random excitation.

***Hysteretic systems.*** Structures responding to earthquake acceleration often exhibit inelastic behavior with the result that the restoring forces are hysteretic in nature. Because significant energy can be dissipated through hysteretic action, analytical methods for predicting inelastic structural response to random excitation are of considerable importance in the design of earthquake-resistant structures.

Wen [58] has shown that the EL method can be used for systems with hysteresis by representing the hysteretic part of the restoring force in terms of a first-order nonlinear differential equation that involves a number of adjustable force parameters. These parameters can be used to adjust the amplitude and shape of the hysteretic loop. This approach to modeling the hysteretic force has the effect of increasing the order of the original system equation, but the EL method -- in contrast to the FPK method -- can readily accommodate this increase in complexity in the governing equations.

This approach can be extended to study the effect of structural degradation as a function of hysteretic action. Because hysteretic energy dissipation is a measure of response severity and duration, structural degradation can be modeled by treating the force parameters in the differential equation for the hysteretic force as functions of energy dissipation. In this way stiffness or strength (or combined) degradation can be treated fairly readily [59-61]; if the parameters that control degradation vary slowly with time, the resulting model can be linearized in closed form. The method has recently been applied to multi-degree-of-freedom shear beam structures [59, 61] and to strong girder and strong column, two-story, one-bay frames using a discrete hinge concept borrowed from deterministic frame analysis [60].

An alternative approach to the linearization of randomly excited systems with hysteretic behavior has been proposed [62-64]. The response is represented as a low-frequency drift plus a remaining process, which is treated as linear by introducing effective damping and stiffness parameters. Thus, each inelastic restoring element is replaced by an effectively linear element; effective viscous damping elements are introduced to represent the energy loss due to hysteresis. Comparison with digital simulation estimates showed reasonably good agreement. In a related approach proposed recently [65] a bilinear, hysteretic yielding system was analyzed by replacing the nonlinear system with a higher-order linear substitute. It was shown that, if the parameters of the substitute system are chosen carefully, the response statistics of the yielding system can be accurately predicted. Results were presented for the specific case of Gaussian white noise excitation.

***Other applications.*** Richard and Anand [66] have recently applied the method of equivalent linearization to a study of string response under planar narrow-band excitation. They showed that the mean square deflection is triple valued, as in the case of harmonic excitation, provided the excitation bandwidth is smaller than a critical value; this value is a monotonically increasing function of the intensity of the excitation. Almost sure asymptotic stability was investigated; it was demonstrated that, under certain conditions, the planar response can be unstable due either to an unbounded growth of the in-plane component of motion or to a spontaneous appearance of an out-of-plane component.

In another application of the EL method, Ibrahim and Soundrarajan [67] investigated the statistical response of the free surface of a cylindrical container partially filled with liquid and subjected to wide-band random excitation. This study has application to the design of liquid storage containers excited by earthquakes. They compared the predictions of two methods -- EL and a Gaussian closure scheme for the moment equations -- with experimental observations and concluded that the EL method gave the best predictions, particularly in the case of high levels of excitation.

The techniques of statistical and harmonic linearization have been combined in a study of the response of nonlinear systems to combined random and periodic forces [68]. The system was a Duffing oscillator driven by white noise and by a sinusoidal force; expressions were obtained for the correlation function and spectral density of the oscillator displacement in terms of the system parameters. A detailed analysis of the equivalent linear oscillator was used to establish ranges of parameter values in which the applied periodic force appreciably affects the spectral density of the oscillator response.

***Nonstationary problems.*** In principle the EL method can be readily applied in cases in which the excitation and response processes are nonstationary. However, the introduction of nonstationarity can considerably increase the complexity of the calculations.

A recent method for computing nonstationary mean square responses by the EL method is based on the use of a recurrence algorithm [69, 70]. There was good agreement with digital simulation estimates. A system with bilinear hysteresis has been studied [70]. Hysteretic behavior was dealt with by introducing an additional state variable governed by a nonlinear differential equation; this procedure has been used elsewhere [58-61]. The excitation process considered was a stationary one with an exponentially decaying harmonic correlation function; the process was modulated by either a unit step envelope function or an exponentially decaying envelope function. Ahmadi [71, 72] has demonstrated that the calculations for nonstationary excitation can be simplified if the strength of the excitation varies only slowly with time. He studied a second order system with a small degree of nonlinearity and proposed several approximate methods based on the assumption that the equivalent linear parameters vary slowly with time [71]. A Duffing oscillator was considered in detail; excitation consisted of white noise modulated by a slowly varying deterministic function. The same approach was used to study the nonstationary response of an oscillator with a set-up spring [72]. Applications of the results to the design of earthquake-resisting foundations were briefly described.

***Generalizations of the equivalent linearization method.*** Two approaches to a generalization of the EL method have been recently proposed with a view to improving its accuracy [73-75]. A second-order EL method was proposed that involves the use of second-order probabilistic functions to evaluate the linearized stiffness and damping parameters [73]. This approach leads to frequency-dependent parameters in contrast to the standard first-order EL method, which gives parameters that are invariable with respect to frequency. So-called linearization functions for typical nonlinearities are introduced and considerably simplify the computation required. The method was applied to a number of specific nonlinear elements; the relationship between first-order and second-order methods was discussed.

As mentioned earlier, a limitation of the standard EL method is that the equivalent linear model has a Gaussian response; thus, information on the deviation due to the presence of nonlinearities cannot be derived. Such information and improved estimates of response statistics can be found, however, by assuming an adjustable, non-Gaussian probability density function p(x) for the response. Parameters are determined from response moment relationships derived directly from the equation of motion. If a truncated Gram-Charlier expansion is chosen for p(x), this method can be regarded as a generalization of equivalent linearization because the first term of the expansion is Gaussian, and results identical to those of the standard EL method can be obtained [74-80]. The practical implications of this approach have been examined recently [74, 75]. Terms to 4th order in the expansion for p(x) have been included [74]; a simple generating function was derived that allows analytical evaluation of the required integrals. Comparisons were made between theoretical predictions and corresponding digital simulation results. Crandall [75] investigated an oscillator with a nonlinear restoring force excited by white noise and compared results from the generalized EL method with the exact solution obtained from the Fokker-Planck equation. He observed steady convergence toward the exact solution as the order of the highest terms in the expansion for p(x) was increased; but convergence was much slower for the expected frequency than for the mean square.

## SIMULATION METHODS

For difficult problems that defy analysis a useful procedure is a simulation study. Such a study involves generating sample functions of the excitation process, computing the corresponding sample functions of the response process (using the equation of motion), and processing the sample response functions to form estimates of the statistical parameters of interest. Simulation is also a useful way to check the validity of approximate theoretical methods.

At present digital simulation is most frequently used; the process is carried out with a digital computer using random numbers to generate the excitation sample functions; a numerical integration procedure is used to compute the sample response functions. Recent examples of this approach are available [31, 33-38, 43, 44, 53, 54, 81].

Analog computer simulation studies are occasionally undertaken. In one such investigation a Duffing oscillator driven by white noise was considered for a wide range of parameter values [82]. Emphasis was placed on estimating the spectral density of the respc ; comparisons were made with results from the equivalent linearization method.

## OTHER METHODS

A Wiener-Hermite series expansion of an arbitrary random process has been applied to the analysis of a Duffing oscillator driven by modulated white noise [83]. Both the excitation and response processes were expanded on a Wiener-Hermite set; the series were truncated after the third terms. Equations for the time development of the appropriate Kernel functions were derived and solved by an iterative technique. Mean square responses as functions of time were obtained for various ranges of damping coefficients and for various degrees of nonlinearity. Comparisons were made between results from the proposed method and results obtained by the perturbation method. It was concluded that the proposed method is useful for analyzing nonlinear systems with large nonlinearities; in such cases the perturbation method is not applicable.

Bendat and Piersol [84] studied the behavior of nonlinear systems with square-law elements driven by random, Gaussian excitation processes; they emphasized frequency domain properties. Nonlinear coherence functions were defined that determined the proportion of the output spectra due to the nonlinear operations. The authors indicated extensions of their analysis to other types of nonlinear models.

Robson [85] investigated the non-Gaussian response of a simple polynomial nonlinear element to Gaussian excitation. He derived correlation functions and spectral densities up to the fourth order in terms of the second order correlation function and spectral density of the excitation. He demonstrated that a response process can be modeled in a simple fashion through a suitable choice of excitation and nonlinearity parameters. Such modeling can be used to provide higher order descriptions of a random process having any prescribed spectrum, skewness, and kurtosis.

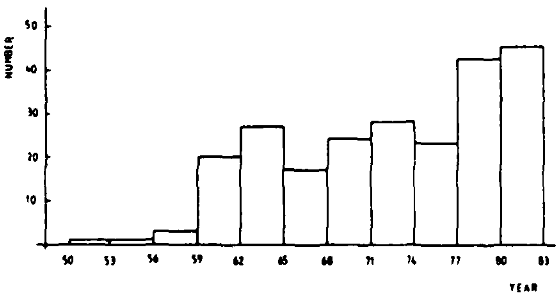
Lindgren [86] has studied the motion of a car wheel traveling over a random surface. He accounted for the fact that the wheel can sometimes lose contact with the ground -- i.e., jump -- for a short period of time. He presented a switching differential equation for use in simulation work and a probabilistic analysis for the movement of the wheel following a jump. He described the conditional distribution of the wheel elevation after a jump by a Slepian model process; such a process can be used to describe average behavior after a jump.

Wedig [87] analyzed the response of oscillators with restoring forces that are piecewise-linear. The method assumes that the multi-dimensional response distributions are piecewise Gaussian and that these distributions are matched together using continuity and normalization conditions. The technique yields an expression for the spectral density of the response process. In an application to an oscillator with a cracked restoring element he found that there are two resonances in the response; the distance between the peaks is a measure of the damage extension. For oscillators with piecewise progressively increasing stiffness the analysis can be extended to yield amplitude-frequency distributions that are analogous to well-known results for the deterministic Duffing oscillator.

The large number of possible motions (or trajectories) of which a nonlinear system is capable has been studied by assuming that the probability distribution of the initial states is known [88]. The global behavior of the system was then analyzed by determining how, as time increases, the trajectories are distributed in state space. The probabilistic formulation led to a set of linear ordinary differential equations that could be studied by applying the theory of Markov processes.

## CONCLUDING REMARKS

The field of nonlinear random vibration is still in a very active state of development, and considerable progress has been made during the last three years. It seems that further progress will be possible through the development of approximate methods based on the FPK method; these include the stochastic averaging technique. An integration of approximate FPK solutions with results from equivalent linearizations, or generalizations of this technique, should lead to additional useful results.



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# LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains an article about vibration analysis of highway bridges.

Dr. H.V.S. GangaRao of the Department of Civil Engineering, West Virginia University, Morgantown, West Virginia has written a review of literature from 1976-1983 and part of 1984 that deals primarily with the effects of free and forced vibrations of a wide class of highway bridges.

# RESEARCH IN VIBRATION ANALYSIS OF HIGHWAY BRIDGES

H.V.S. GangaRao*

*Abstract. This paper is a review of literature from 1976-1983 and part of 1984 that deals primarily with the effects of free and forced vibrations of a wide class of highway bridges. Recent research concerned with the effects of earthquakes, impact and dynamic response of concrete and steel girder-slab bridges, free and forced vibration of cable-stayed and suspension bridges, and vehicle-structure interactions under moving loads is summarized.*

A previous paper [10] reviewed the vibration analysis of highway bridges according to classical theories and equations of motion presented by Willis, Stokes, Kriloff, Timoshenko, and Inglis. The use of high-speed computers allowed significant progress in research on vibration analysis of highway bridges; several important research articles have appeared in the literature. These articles have been summarized [10].

## THEORETICAL STUDIES

When slab-stringer highway bridges are idealized as beams and the flexibility along their widths ignored, the bridges can be mathematically represented under dynamic loads for flexural and torsional vibrations as

$$[M_f]\{\ddot{w}\} + [C_f]\{\dot{w}\} + [K_f]\{w\} = \{F_f\} \qquad (1)$$

$$[M_t]\{\ddot{\theta}\} + [C_t]\{\dot{\theta}\} + [K_t]\{\theta\} = \{F_t\} \qquad (2)$$

The equation of motion for the vehicle model is

$$[M_v]\{\ddot{v}\} + [C_v]\{\dot{v}\} + [K_v]\{v\} = \{F_v\} \qquad (3)$$

where,

$[M_f]$, $[M_t]$, and $[M_v]$ = mass matrices in flexure, torsion, and vehicle

$[C_f]$, $[C_t]$, and $[C_v]$ = damping matrices in flexure, torsion, and vehicle

$[K_f]$, $[K_t]$, and $[K_v]$ = stiffness matrices in flexure, torsion, and vehicle

$F_f$, $F_t$, $F_v$ = forcing function in flexure, torsion, and vehicle

$w(x,t)$, $\theta(x,t)$ = vertical and rotational displacements at distance x, time t

$v(x,t)$ = degrees of freedom of vehicle model

The above equations can be solved by various numerical techniques, including Runge-Kutta and predictor-corrector methods. A few closed form or series solutions are available for vehicles represented by constant or alternating forces with a single mass. The numerical methods commonly used in the literature have been presented in some detail by Hathout [11].

Wills [26] conducted a vertical vibration analysis of bridges. He idealized the bridge as a beam and neglected vehicle-induced vibrations, rotary inertia, stress deformations, and damping effects; i.e., he used a simplified version of equation (1). He obtained good correlation between the theoretical fundamental frequencies of nine bridges and those measured in the field. For higher modes the correlation was less satisfactory in the sense that the theoretical frequencies exceeded the measured values. The correlations of frequencies and mode shape for the cantilever and suspended span structures were satisfactory when the structure was assumed to have acted as a continuous beam. The natural frequencies of 18 simply-supported, prestressed-concrete I-girders with concrete decks and without skew were determined [16] using the finite element method and compared with those from the equivalent beam method. It

*Professor of Civil Engineering, West Virginia University, P.O. Box 6101, Morgantown, WV 26506

was found that an accurate estimate of the fundamental bridge frequency can be obtained through this approach, but results were poor for other dynamic characteristics. It is of interest that the slab contribution must be included in the analysis.

Green [7] conducted dynamic response studies of highway bridges by including heavy vehicle-induced vibrations with the superstructure vibrations. He found that the superstructure response is a function of riding surface roughness; speed, bounce, and pitch frequencies of vehicles; and the longitudinal flexural frequency of the superstructure. He concluded that a dynamic interaction between a heavy vehicle and a superstructure was present with a longitudinal flexural frequency between 2 and 5 Hz and that the interaction resulted in a quasi-resonance phenomenon with median dynamic deflection values in excess of 0.3 of the static value.

Hathout [11] recognized that vehicle-induced vibrations are not adequately represented by static responses -- i.e., strain-time histories leading to dynamic stress/displacement components of substantial magnitude added to live load stresses. For design against fatigue, he developed a mathematical model in the elastic range of deformation that included vehicle-induced motions to predict the flexural-torsional vibration of highway bridges. Hathout also studied the influence on the response of simple as well as multi-span bridges by varying several problem parameters. He concluded that the dynamic response of a simply supported bridge can be achieved by superimposing the effects of the first three modes for both bending and torsion; reducing torsional/bending rigidities increases the dynamic coefficients associated with torsion/bending.

However, speed, shape, and size of undulations as well as bump locations have a greater influence on the dynamic coefficients of bridges. The dynamic coefficients associated with the torsional response can be greater than those of the bending response; hence, torsional effects can be more important than bending effects. Vehicle damper nonlinearity seems to have little effect on the dynamic wheel load. The bounce and pitch motions of the vehicle are coupled in all modes of vibration. For continuous bridges the effect of an undulation on the dynamic response appeared to be greater than an isolated bump. According to Hathout [11] impacts in bending and torsion, skewness, and nonuniform velocities of many moving vehicles need thorough researching before pertinent questions regarding the dynamic response of straight bridges can be answered.

Machida and Matsuura [17] dealt with vehicle-induced responses of concrete railway bridges; they concluded that bridge response is affected by vehicle speed, track/wheel irregularity, and loading frequencies. These are similar to observations made by other authors. In addition, they concluded that the influence of a bump or track level difference on dynamic load factors of a concrete bridge is greater for shorter spans than for longer spans. Machida and Matsuura correctly pointed out that deflection limits based on girder length to depth ratio were excellent guides for minimizing steel girder vibrations; however, deflection limits were of little help in obtaining the vibration limit-state for concrete bridges.

Gupta [8, 9] derived the equations of motion for slab-stringer bridges from the kinetic and potential energy expressions by using the Lagrange method. These equations of motion in terms of independent horizontal and vertical coordinates are similar to the expressions given equations (1), (2), and (3). Gupta studied parameters such as vehicle speed, braking functions, initial bounce, and road surface irregularities with reference to vehicle-induced vibrations and impact factors for bending and deflection. He concluded that the impact factor due to simultaneous braking and bounce is about 15% higher than the impact from bounce or braking. Beam type idealizations of deck stringer bridges resulted in higher impact factors than did two-dimensional plate idealizations. Therefore, the transverse flexibility of a bridge must be considered in a realistic manner so as not to complicate the mathematical modeling and make the computations cumbersome.

Hayashikawa and Watanabe [12] developed a lateral vibrational response analysis of bridges under a moving load using the differential equation of beams in a manner similar to that of Wills [26]. The authors have extended their modal method of analysis to non-prismatic continuous bridges by determining eigenvalues and eigenfunctions for arbitrary boundaries. The most important conclusions of their findings were that dynamic amplification factors increased with speed and that, for simply supported beams, amplification was greater than for continuous beams.

A vast amount of literature exists on vehicle-structure interactions in bridge dynamics [18, 19, 27]. Recent developments in analytical and numerical approaches for solving dynamic interactions of bridges and moving vehicles have been discussed [23].

Cable-stayed and suspension bridges are more flexible than slab-stringer systems, and their dynamic behavior can constitute serious vibrational problems. Therefore, research concerning problems of cable-stiffened bridges such as design wind speed, response against wind, aerodynamic stability against flutter, and establishment of specifications for wind-resistant design against vibration has been performed over the past six years [1, 2, 4, 14, 15, 20]. Abdel-Ghaffar [1] developed a method based on a linearized finite-element theory for free vibration of suspension bridges. The analysis included the vertical, torsional, and lateral modes of linear free vibration by accounting for the elasticity of cables and deformations of towers. The potential and kinetic energies of a bridge were used to derive element and global stiffness matrix equations of motion; Hamilton's principle was used to form an eigenvalue problem. Abdel-Ghaffar [2] extended the linear theory and analysis of vibration of suspension bridges to nonlinear free coupled vertical-torsional vibrations. He presented approximate solutions using perturbation techniques. Amplitude-frequency relationships were derived for a combination of coupled, but varying, magnitudes of vertical vibrations and torsional vibrations that might be present in a bridge.

Hayashikawa and Watanabe [13, 14], on the other hand, presented an analytical method to determine natural frequencies and mode shapes of multi-span suspension bridges. They used linearized fourth order differential equations and accounted for the support conditions of stiffening girders and the flexural stiffness of towers. In addition, they developed dynamic response expressions under moving loads with constant velocity in closed form through modal analysis; responses at any point on a bridge and at any time can thus be easily obtained. They concluded that the effect of the support conditions of stiffening girders is considerable; i.e., hinged girders had a larger natural period than continuous ones. Cable support conditions at the tower top seem to have a negligible effect on bridge natural frequencies. The dynamic amplification factors increase with vehicle speed [14]; this is similar to deck-stringer bridges.

The dynamic behavior of cable-stayed bridges to moving loads has been theoretically investigated [4, 15, 20]; the objectives have been to determine the dynamic increment factors of displacements and forces in main girders and the aerodynamic stability of entire structures under wind-induced oscillations. Komatsu and Kawatani [15] idealized a cable-stayed bridge as a lumped mass system and a moving load as a single-degree-of-freedom system. The results of their analytical studies were compared with dynamic field tests on Toyosato cable-stayed bridge. Mukarami and Okubo [20] studied structural safety due to wind from wind tunnel experiments. The flexural and torsional frequencies from their wind tunnel tests seemed to be in good agreement with their theoretical values. Several wind tunnel tests have also been conducted by Bosch and Cayes [4]; they noted an increase in stiffness of the cable-stayed box-girder. Results of vortex shedding response amplitude and acceleration, critical flutter velocity, flutter derivatives, and static force coefficients have been presented [4].

Recent environmental awareness has forced engineers to take a careful look at allowable acceleration limit, a serviceability limit state, and footbridge decks vibrating under pedestrian loading. This subject has been investigated [3, 24] in terms of pedestrian excitation source, structural response, and acceptance criteria from the human tolerance viewpoint. Various types of foot-bridges under simulated pedestrian loading have been analyzed [3]; a simple expression was obtained for finding the maximum dynamic response. Acceptable levels of human response to bridge vibration have been developed for the design of footbridges so that public concern can be minimized. It has been found [24] that footbridges the first mode natural frequency of which is close to 2 Hz have a higher probability of being excited by increases in pedestrian flow.

Some existing highway bridges have been analyzed for their dynamic response under the load of a walking man. The conclusion was that such dynamic effects are well within the existing allowance of static live load; i.e., the impact factor.

## EXPERIMENTAL STUDIES

Measurements of dynamic response of bridges due to traffic and wind are usually obtained to reassess bridge specifications. Excellent research articles have been published in the literature over a period of time [6, 7, 24]. However, the recent trend in the dynamic testing of bridges has been to predict deterioration of bridge superstructure; such predictions can be useful in maintenance planning and safety. Stephens [22] conducted dynamic tests of concrete bridge decks in which the propagation of forced vibration through a bridge deck was related to concrete quality and deck condition at the time of dynamic load testing. Correlation was established between the magnitude of amplitudes at different deck locations and deck deterioration. However, this approach will require refinements before it can be used to accurately predict the magnitude and location of deterioration for several types of superstructures made of different construction materials.

Changes in dynamic properties of a three-span highway bridge have been evaluated as a possible means for detecting structural deterioration due to fatigue cracks in girders [21]. Dynamic tests were conducted to find viscous damping ratios, stiffness, and mechanical impedance at selected intervals during loading. The results showed that changes in bridge stiffness and vibration signatures can be correlated to structural deterioration. Early changes in mechanical impedance plots were related to deck deterioration; subsequent changes were related to fatigue cracks in steel girders.

## RESEARCH NEEDS

Research is needed in preparing design aids based on rational methods of analysis for dynamic live load allowances due to traffic loading on higway bridges and for probabilistic dynamic traffic load increments. These needs have been examined by the subcommittee on loads and forces on bridges of the ASCE committee on bridges [29]. The need to measure braking (longitudinal) forces and the effects of bridge inertia on the transmission of these forces to substructures have also been discussed [29].

However, Wheeler [25] questioned the need for such extensive research into dynamic live-load allowance factors. He concluded that, because resonant or quasi-resonant behavior under vehicle loading is random and complex, it is virtually impossible to quantify parameters that affect dynamic live-load allowance factors. He further stated that little will be gained by further research other than treating dynamic allowance as a random variable using a probabilistic approach. At any rate some of Wheeler's comments should be viewed in a proper perspective before any comprehensive research program [29] is undertaken.

Proceedings of a workshop on earthquake resistance of highway bridges [28] contained the summaries of current state of the art and practice as well as research needs on seismic/dynamic aspects of highway bridge design. It was emphasized that analytical and experimental research should be integrated, and both simple and sophisticated methods of analysis be verified by experiments and/or field measurements on actual bridges. However, workshop participants agreed to study the dynamic behavior of materials, simplified structural systems, and composite structures through laboratory experiments. It was also stated that ground motion effects should be considered as they relate to foundations, abutments, and superstructures. Primary recommendations were to:

- assess current knowledge and practice of bridge design during earthquakes
- evaluate the relevance of present research results to actual user needs
- recommend means for effective cooperation between researchers and professional users
- develop strategies for rapid dissemination and evaluation of research findings that might be beneficial to a designer

Several researchers are currently working on some of these objectives to predict the behavior of highway bridges under earthquake loads. It is too early to predict the relevance of present research findings to user needs.

## CONCLUSIONS

This review article is divided into theoretical studies, experimental studies, and research needs in the area of vibration analysis of highway bridges. Recent research results of dynamic responses of slab-stringer bridges, suspension and cable-stayed bridges, and vehicle-structure interaction are critically reviewed. A new experimental trend to evaluate the changes in dynamic properties of bridges as a possible means for detecting structural deterioration is presented. Earthquake effects on highway bridges are being researched intensely to evaluate the relevance of present research results to actual user needs; emphasis is given to study of ground motion effects and their relation to foundations, abutments, and superstructures.

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# BOOK REVIEWS

## EINFUHRUNG IN THEORIE UND PRAXIS DER ZEITREIHEN UND MODALANALYSE (INTRODUCTION TO THE THEORY AND PRACTICE OF TIME SERIES AND MODAL ANALYSIS)

H.G. Natke
Friedrich Vieweg-Verlagsgesellschaft
Braunschweig/Wiesbaden
1983, 522 pages, 148 DM (in German)

The vibration analysis of elastomechanical systems is important in aerospace and aircraft technology, the automotive industry, and the machine tool industry. Because of the uncertainties that always exist in theoretical analysis, experimental procedures for the identification of vibrating systems have become increasingly important. Rapid developments in this field have been strongly influenced by enormous progress in the area of electronic measurement and processing equipment. A large number of publications about system identification and experimental modal analysis is now available; unfortunately, until now a summarizing description had not been published.

The author of this book has given a comprehensive and excellent presentation of experimental identification procedures and their applications to structural dynamics. First, important theoretical information is given on dynamics of linear systems, statistics, stochastics, and analysis of time series. Succeeding chapters deal with direct and indirect identification methods and their relation to practical problems. Concentration on linear time-invariant and discrete systems has enabled the author to provide a clear presentation.

The introductory chapter contains a classification of the identification problem within other structural problems and points out different characteristics of identification procedures. Chapter 2 treats fundamentals for the investigation of deterministic processes in linear time-invariant vibrating systems in both the time domain and the frequency domain. A signal classification is followed by input-output relationships for deterministic single-degree-of-freedom and multi-degree-of-freedom systems by means of frequency response and weighting (impulse response) functions. Important problems concerning discretization and signal transformation (Fourier transformation, z transformation) are also discussed.

In practice deterministic signals always contain superimposed stochastic signal parts caused by noise. On the other hand, test signals themselves can be chosen as random signals. In such cases statistical methods must be applied to describe the stochastic dynamic processes in systems. Chapter 3 introduces statistics and stochastics and defines correlation functions (time domain) and spectral functions (frequency domain). By means of these functions the relationships between stochastic input and output signals can be defined. This chapter also treats the fundamentals of estimation theory, which is very important for parameter determination procedures.

The remaining chapters are devoted to identification methods and applications. Chapter 4 deals with nonparametric identification, which is often used to describe linear processes, to determine periodic signal parts, to locate noise sources, and to identify possible defects in an early state. Nonparametric identification uses models without structure; system characteristics are represented by frequency response functions, weighting functions, and transfer functions in tabulated or graphic form. This chapter also contains a review about different artificial excitation possibilities.

Parametric identification, described in Chapter 5, has particular significance for the vibration analysis of elastomechanical systems. Contrary to nonparametric identification the mathematical formulation of dynamic systems requires a structural model. The input-output relations are expressed by structural parameters, which must be identified. They can be subdivided into direct parameters (inertia, damping, and stiffness) and indirect parameters (eigenvalues and natural modes).

As mentioned above parametric identification is based on knowledge of input-output equations. Therefore, the vibration theory of linear multi-degree-of-freedom systems is given first in Chapter 5. Natural as well as forced vibrations are derived for different types of systems (without damping, viscous damping, structural damping). Important connections between input-output quantities and the system parameters are shown. Both well known procedures of parametric identification -- the classical phase resonance method and the modern phase separation method -- are discussed and compared.

Parametric and nonparametric identification are known as direct methods. Chapter 6 has to do with indirect identification. In this case the problem is to correct system parameters of a corresponding computational model by means of experimental results; e.g., parametric identification. This correction is an identification procedure. The author describes procedures for solving the indirect identification; it is currently a topic of investigation in various research projects.

The author has written a very interesting book, which contains up-to-date knowledge about identification methods for linear elastomechanical systems. Both theoretical fundamentals and practical applications are included. The various procedures are critically compared and indications are given for existing unsolved problems. Each chapter contains a set of exercises with solutions. The reader can thus apply the derived formulas to practical requirements. The references provide the reader with information for further specialization in this important area. The book can be recommended as textbook for students who have basic knowledge in mathematics and mechanics. Furthermore, it is a valuable tool for mechanical engineers working in the field of structural dynamics and identification.

R. Nordmann
Fachbereich Maschinenwesen
Universität Kaiserslautern
D6750 Kaiserlautern, West Germany

## FUEL-AIR EXPLOSIONS

Proc. Intl. Conf., McGill Univ., Montreal, Canada
Nov 4-6, 1981, SM Study No. 16
J.H.S. Lee, C.M. Guirao, and D.E. Grierson, eds.
Univ. of Waterloo Press, Waterloo, Ontario, Canada
1982

The title and subtitle indicate the contents of this long book. The texts of the 40 papers included have to do with the following: combustion and explosions in gas-air mixtures, dust-air mixtures, and hybrid mixtures with both combustile gases and dust mixed with air. Following each paper are comments from conference attendees and replies by the authors.

The papers are organized in eight parts:

Part 1 -- Flammability Limits
Part 2 -- Turbulent Deflagration
Part 3 -- Gas Phase Detonations
Part 4 -- Liquid Spray Detonations
Part 5 -- Dust Explosions
Part 6 -- Numerical Modelling
Part 7 -- Large Scale Test Facilities and Results
Part 8 -- Reports on Current Activities

Following the papers is a ninth section that includes seven sets of summary remarks on key topics of the conference.

For anyone having more than a casual interest in accidental or planned fuel-air explosions and what was known about such explosions at the time of this conference, this book is an essential reference. The organizers and editors have succeeded in collecting under one cover papers by most of the scientists and engineers active in research aimed at extending knowledge of the very complex physical processes occurring in these classes of explosions. They have also succeeded in presenting this material in as logical a fashion as is possible, given 40 authors discussing a wide variety of subtopics and 40 different styles of writing or presentation.

The last two parts contain reports on activities then current in many research laboratories and summary remarks in seven research areas. These two parts are particularly valuable because they highlight the many unknowns in fuel-air explosions. They also contain opinions of highly respected investigators in this field on desired directions for future research activities.

The conference was a gathering of specialists in fuel-air explosion research. As such, although most of the papers are well written and clearly presented, they are clearly not for the neophyte. The level of presentation presupposes a working knowledge of at least the basic physics of gas combustion and detonation processes. Many experimental papers also presuppose a working knowledge of experimental methods for studying these classes of explosions.

If there is a lack in the topic coverage, it is in the effects of fuel-air explosions, as opposed to the physics of the processes occurring in such explosions. Neither the characteristics of blast waves generated by these explosions when they occur in the open nor the distinct differences in many effects compared to those from detonating condensed explosives are covered by any author. But, perhaps inclusion of papers on effects would have too greatly enlarged the already extensive coverage of the book or diluted coverage of the poorly-known and complex physics of these explosions. In any case this book will certainly be a valuable addition to my reference shelf for years to come.

W.E. Baker, President
Wilfred Baker Engineering
218 E. Edgewood Place
San Antonio, TX 78209

## EARTHQUAKE DESIGN OF CONCRETE MASONRY BUILDINGS VOL. 1. RESPONSE SPECTRA ANALYSIS AND EARTHQUAKE MODELLING CONSIDERATIONS

R.E. Englekirk and G.C. Hart
Prentice-Hall, Inc., Englewood Cliffs, NJ
1982, 144 pages, $28.95

Dynamic analysis now plays a predominant role in building design. As stated by the authors, "this book . . . presents the essential background material for the calculation of earthquake loads on buildings by means of response spectrum analysis . . . it also applies to other types of buildings." The authors assume that the engineer has a limited knowledge of dynamics but a good basic knowledge of statics. They intend to acquaint him with dynamics and response spectra.

The book contains six chapters and two appendices. Chapter 1, an introduction to earthquake design, describes basic shear force, shear demand, and shear capacity and contains an overview of earthquake design. Chapter 2 is concerned with ground motion due to earthquakes. Included are ground aspects -- i.e., focus, epicenter and focal depth -- the Richter scale, modified Mercalli intensity (MMI), the time history of earthquake ground motion, and an earthquake design spectrum. Several spectral quantities are identified -- displacement, velocity, and acceleration -- and elaborated with simple response spectra.

Chapter 3, which focuses on static earthquake design forces, contains information about base shear force, lateral story forces, and proposed design procedures employing the seismic design coefficient. Examples are used to illustrate the principles. Chapter 4 describes the modeling of shear wall buildings, including the response of structures to ground motion, shear wall and floor diaphragms, and flexible and rigid floor diaphragms. Rayleigh's method is employed to determine the natural frequency of the combination of shear wall and floor systems. The examples are excellent.

Chapter 4 covers shear wall response using elastic response spectra. The displacement of shear wall substructure, the fundamental mode response of spectral analysis, damping, and empirical relationships for the fundamental period of vibration are explained, as are the participation factor used in response analysis of single-degree-of-freedom response spectra. Use in the design procedure of damage level earthquake spectra is covered. Illustrative examples are given as well as simple analytical formulas of the frequencies of infinitely rigid and flexible floor systems for one and two wall structures.

The topic of the final chapter is shear wall response using inelastic response spectra. The concluding section discusses collapse level earthquake spectral design procedures and contains good examples.

Appendix A covers the role of the geotechnical consultant in determining maximum response spectra. The report "Tentative Procedures for Development of Seismic Relations for Buildings" covers damage level spectra and collapse level spectra assuming a building life of 50 years. The probability density function (PDF) is used to determine the responses. Appendix B has to do with multi-degree-of-freedom response spectra analysis.

This book provides good basic coverage for response spectra analysis. The reviewer believes that a table of nomenclature would be helpful to the reader as would some simple computer programs of dynamic analysis. The dynamic analysis of a nonuniform beam would help the reader understand the response of the second order differential equation system. The authors make no reference to structures in which frequencies are very close together. In such cases the root-mean-square (rms) breaks down, and a different formula must be applied.

H. Saunders
1 Arcadian Drive
Scotia, NY 12302

## VIBRATION OF BLADED DISC ASSEMBLIES

D.J. Ewins and A.V. Srinivasan, eds.
ASME, New York, NY
1983, 160 pages

Renewed interest in bladed discs includes structural dynamics, aerodynamics, and aeroelasticity. One question is whether or not a set of blades can be arranged so as to minimize the detrimental effect of mistuning. This is one of the topics of this monograph, which contains 17 papers presented at the Ninth Biennial Conference on Mechanical Vibration and Noise held at Dearborn, Michigan, from September 11-14, 1983.

The first six papers are concerned with the development of analytical methods that could help the designer with structural dynamics; i.e., assembly natural frequencies and forced vibration responses. Frequencies and mode shapes of rotating bladed axisymmetric structures, free and forced vibration of turbine blades, and vibration modes of packeted bladed discs are considered. The last three papers in this group treat the dynamics of last-stage rotor blades for large steam turbines, analysis of friction-damped resonant stresses in turbine blades, and stagger-angle dependence of inertial and elastic coupling in bladed discs. These papers are theoretical and employ either finite elements (axisymmetric, isoparametric, and junction elements), Lagrange equations, or substructuring methods via receptance method coupling. In addition, the Rayleigh-Ritz and the powerful Ritz averaging methods are included. When possible, the authors include experimental results.

The next three papers deal with experimental observations of structural dynamics. Included are modal analysis and parameter identification for twisted compressor blades by means of impulse excitation; measurement of relative vibratory motion at the shroud interface; and an experimental study for obtaining the vibration characteristics of the LP wheel of a steam turbine with tie wires. Analytic efforts rely upon experimental determinations of damping, mode shapes, modal characteristics, frequencies, and vibratory response.

The tenth and eleventh papers describe the combination of aerodynamics and structural aerodynamics. Twin mode analysis of aeroengine fan vibration and flutter for application in design studies is the topic of one paper; the other has to do with measurement of unsteady pressures close to the tip of a transonic fan in unstalled supersonic flutter.

The subject of the next three papers is turbine blade mistuning. The papers cover modal developments and statistical investigation of turbine blade mistuning, resonant vibration levels of a mistuned blade disc, and spectral analysis of mistuned bladed disc assemblies by component mode synthesis. The author of the last paper used a single blade and coupled the otherblades in the group by substructuring. He also employed triangular finite elements for the blade; the reviewer believes that isoparametric elements would be a better choice. The constant reference to a paper in the reference section detracts from this excellent paper. An appendix should have been included that shows how the estimation of the influence of the higher order substructure affects the analysis.

The last three papers deal with mistuning. One describes a discrete model of a multiple blade system attached to a rigid disc. Such an attachment allows blade-to-blade friction damping, blade-to-blade flexibility coupling, blade-to-ground friction damping, and stationary and traveling wave excitation. The effects of mistuning are included. The next paper presents a statistical assessment of the effects of variable root flexibility in the vibration response of shrouded blades. Rather than the expensive Monte Carlo technique for statistical analysis, the author employs a numerical method that involves a local modification of the linear differential equation. The last paper describes the maximum resonant response of a mistuned bladed disc. The authors extend earlier work on the prediction of the maximum resonant response of a mistuned bladed disc with closely spaced dual modes as a function of modal damping and modal mistuning. They present a closed form expression for the maximum forced response.

This is a good monograph. Although much has been accomplished in the last few years, greater effort is required. At present, no definite answer to mistuning is available. Modal analysis of rotating blades is important; perhaps the next conference will include experimental findings on this subject.

H. Saunders
1 Arcadian Drive
Scotia, NY 12302

# SPECTRUM

**Comment on "Engineering Education and Training"**
(R.L. Eshleman, Shock Vib. Dig., 16 (4), p 2, Apr 1984)

**Why Don't Firms Send Employees to Short Courses?**

This is written in response to the "Engineering Education and Training" piece in Editors Rattle Space, April 1984. I agree with you on the value of short courses. But often employers do not agree. Here are some of their "reasons" and some rebuttal that might be useful to employees who want to attend a short, specialized course.

OUR PEOPLE ARE ALREADY EXPERIENCED. Perhaps this is true for some of our people. But perhaps those individuals are ready for promotion. Or retirement. Perhaps they have had one years' experience twenty times, not twenty years' experience. Perhaps our whole department is "out of date." Let's find out.

THERE'S NO MONEY FOR TECHNICAL TRAINING. Then why is there money for "management" training such as equal opportunity courses, courses in avoiding sexual harassment, etc.? Is it perhaps that you, Mr. Manager, are afraid to ask for technical training for us?

OUR PEOPLE GET THAT TRAINING IN COLLEGE. Our people get some theory in college. But very little practical, immediately useful, up-to-date experience.

OUR PEOPLE WOULD BE EXPOSED TO JOB OFFERS. Our good people are exposed to job offers every time they pick up a newspaper or technical magazine. One reason they are tempted to leave is lack of training here. Don't forget to give them raises ***soon*** after they take a course. They are more valuable; don't wait for some other organization to reach that conclusion.

Wayne Tustin
Tustin Institute of Technology
22 E. Los Olivos Street
Santa Barbara, CA 93105

# SHORT COURSES

## OCTOBER

**VIBRATIONS OF RECIPROCATING MACHINERY**
Dates: October 9-12, 1984
Place: Houston, Texas
Objective: This is a new course on vibrations of reciprocating machinery including piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory -- including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic resonance phenomena and digital acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compressors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be emphasized. Case histories and examples will be presented to illustrate techniques.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

**MACHINERY VIBRATION ANALYSIS**
Dates: October 9-12, 1984
Place: Houston, Texas
Dates: November 27-30, 1984
Place: Lisle, Illinois
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow-speed paper rolls.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

**MACHINERY VIBRATION ENGINEERING**
Dates: October 9-12, 1984
Place: Houston, Texas
Dates: November 27-30, 1984
Place: Lisle, Illinois
Objective: Techniques for the solution of machinery vibration problems will be discussed. These techniques are based on the knowledge of the dynamics of machinery; vibration measurement, computation, and analysis; and machinery characteristics. The techniques will be illustrated with case histories involving field and design problems. Familiarity with the methods will be gained by participants in the workshops. The course will include lectures on natural frequency, resonance, and critical speed determination for rotating and reciprocating equipment using test and computational techniques; equipment evaluation techniques including test equipment; vibration analysis of general equipment including bearings and gears using the time and frequency domains; vibratory forces in rotating and reciprocating equipment, torsional vibration measurement, analysis, and computation on systems involving engines, compressors, pumps, and motors; basic rotor dynamics including fluid film bearing characteristics, critical speeds, instabilities, and mass imbalance

response; and vibration control including isolation and damping of equipment installation.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

**VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION**

Dates: October 15-19, 1984
Place: New York, New York
Dates: November 5-9, 1984
Place: San Francisco, California
Dates: December 3-7, 1984
Place: Huntsville, Alabama
Dates: February 4-8, 1985
Place: Santa Barbara, California
Dates: March 11-13, 1985
Place: Washington, D.C.
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos Street, Santa Barbara, CA 93105 - (805) 682-7171.

**ELECTROEXPLOSIVES DEVICES**

Dates: October 16-19, 1984
Place: Philadelphia, Pennsylvania
Objective: Topics will include but not be limited to the following: history of explosives and definitions; types of pyrotechnics, explosives and propellants; types of EEDs, explosive trains and systems, fuzes, safe-arm devices; sensitivity and functioning mechanisms; output and applications; safety versus reliability; hazard sources; lightning, static electricity, electromagnetic energy (RF, EMP, light, etc.), heat, flame, impact, vibration, friction, shock, blast, ionizing radiation, hostile environments, human error; precautions, safe practices, standard operating procedures; grounding, shorting, shielding; inspection techniques, system check-out troubleshooting and problem solving; safety devices, packaging and transportation; specifications, documentation, information sources, record keeping; tagging, detection and identification of clandestine explosives; reaction mechanisms, solid state reactions; chemical deactivation, disposal methods and problem, toxic effects; laboratory analytical techniques and instrumentation; surface chemistry.

Contact: E&P Affairs, The Franklin Research Center, 20th and Race Streets, Philadelphia, PA 19103 - (215) 448-1000.

**MECHANICAL ENGINEERING (POWER GENERATION)**

Dates: October 22-26, 1984
Place: Carson City, Nevada
Objective: Emphasizes the mechanisms behind various machinery malfunctions. Problems associated with rotating equipment used for power generation are highlighted. The seminar is designed for mechanical, maintenance, and machinery engineers who are involved in the design, acceptance testing, and operation of rotating machinery. Other topics include data for identifying problems and suggested methods of correction. The seminar also includes a lab session.

Contact: Bob Grissom, Customer Training Department, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-9315.

**UNDERWATER ACOUSTICS AND SIGNAL PROCESSING**

Dates: October 22-26, 1984
Place: State College, Pennsylvania
Objective: The course is designed to provide a broad, comprehensive introduction to important topics in underwater acoustics and signal processing. The primary goal is to give participants a practical understanding of fundamental concepts, along with an appreciation of current research and development activities. Included among the topics offered in this course are: an introduction to acoustic and sonar concepts, transducers and arrays, and turbulent and cavitation noise; an extensive overview of sound propagation modeling and measurement techniques; a physical description of the environment factors affecting deep and shallow water acoustics; a practical guide to sonar electronics; and a tutorial review of

analog and digital signal processing techniques and active echo location developments.

Contact: Alan D. Stuart, Course Chairman, Applied Research Laboratory, The Pennsylvania State University, P.O. Box 30, State College, Pa 16801 - (814) 863-4128.

## NOVEMBER

### RELIABILITY ENGINEERING AND MANAGEMENT

Dates: November 26-30, 1984
Place: Tucson, Arizona
Objective: Emphasis will be on system reliability prediction, reliability testing, mechanical reliability, burn-in testing, dormancy reliability, software reliability, life-cycle costing, design to cost, maintainability, availability, safety, liability, quality and their management.

Contact: The Office of Special Professional Education, College of Engineering, Harvill Bldg. No. 76, Box 9, The University of Arizona, Tucson, AZ 85721 -- (602) 626-3054.

## DECEMBER

### FIELD INSTRUMENTATION AND DIAGNOSTICS

Dates: December 3-6, 1984
Place: Houston, Texas
Objective: To provide a balanced introduction to diagnostic instrumentation and its applications for evaluating rotating machinery behavior. The seminar also covers fundamental rotating machinery behavior and some of the more common machinery malfunctions. It includes a lab session with workshops on data acquisition instrumentation, balancing, oil whirl/whip and rubs, and monitor system calibration.

Contact: Bob Grissom, Customer Training Department, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-9315.

## MARCH

### PENETRATION MECHANICS

Dates: March 18-22, 1985
Place: San Antonio, Texas
Objective: This course presents the fundamental principles of penetration mechanics and their application to various solution techniques in different impact regimes. Analytical, numerical, and experimental approaches to penetration and perforation problems will be covered. Major topic headings of the course are: fundamental relationships, material considerations, penetration of semi-infinite targets, perforation of thin targets, penetration/perforation of thick targets, hydrocode solution techniques, experimental techniques. Discussions will include such topics as fragment or projectile breakup, obliquity, yaw, shape effects, and richochet. Shock propagation, failure mechanisms and modeling, constitutive relations, and equation-of-state will be presented in the context of penetration mechanics. Developed fundamental relationships will be applied in the following areas: hypervelocity impact, long rod penetration; spaced and composite armors, explosive initiation, hydrodynamic ram, fragment containment, earth penetration, crater/hole size, spallation, shaped charge penetration.

Contact: Ms. Deborah J. Stowitts, Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78284 - (512) 684-5111, ext. 2046.

### VIBRATION CONTROL

Dates: March 26-29, 1985
Place: Washington, D.C.
Objective: This vibration control course will include all aspects of vibration control except alignment and balancing. (These topics are covered in separate Institute courses.) Specific topics include active and passive isolation, damping, tuning, reduction of excitation, dynamic absorbers, and auxiliary mass dampers. The general features of commercially available isolation and damping hardware will be summarized. Application of the finite element method to predicting the response of structures will be presented; such predictions are used to minimize structural vibrations during the engineering design process. Lumped mass-spring-damper modeling will be used to describe the translational vibration behavior of pack-

ages and machines. Measurement and analysis of vibration responses of machines and structures are included in the course. The course emphasizes the practical aspects of vibration control. Appropriate case histories will be presented for both isolation and damping.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

## MAY

### ROTOR DYNAMICS

Dates: May 6-10, 1985

Place: Syria, Virginia

Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

# NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

## CALL FOR PAPERS

### BEIJING INTERNATIONAL GAS TURBINE SYMPOSIUM AND EXPOSITION
**September 1-4, 1985**
**Beijing, People's Republic of China**

The Gas Turbine Division of The American Society of Mechanical Engineers announces the first Beijing International Gas Turbine Symposium and Exposition to be held in Beijing, the People's Republic of China, in 1985. The Symposium will be held September 1-4; the Exposition will be open September 2-7 in the Beijing Exposition Centre. The 7th International Symposium on Air Breathing Engines will be held in Beijing during the week following the Symposium. The Symposium is being co-sponsored by the ASME Gas Turbine Division; the Chinese National Aero-Technology Import and Export Corporation; and the Chinese Society of Aeronautics and Astronautics. Although similar to the annual International Gas Turbine Conference and Exhibit which is now entering its 30th year, the Beijing Symposium will be held in addition to that Conference.

The focus of the Symposium will be on applied technologies. Papers on gas turbine technology are invited with particular emphasis on aviation applications, aero-engine derivatives for land-based and off-shore power generation, and driven equipment. Within these areas, papers concerning design, fabrication, manufacturing, metallurgy, controls and diagnostics, test and measurement technology, and coal utilization are particularly encouraged.

Authors wishing to submit a paper should forward an abstract by November 1, 1984 to the program chairman: Arthur J. Wennerstrom, AFWAL/POTX, Wright-Patterson AFB, OH 45433.

Completed manuscripts must be received by January 15, 1985. All papers submitted will be reviewed in accordance with established ASME and Gas Turbine Division policy and procedures and will be eligible for ASME journal publication when the reviews justify it.

For further information contact: The International Gas Turbine Center, 4250 Perimeter Park South, Suite 108, Atlanta, GA 30341 - (414) 451-1905.

### SYMPOSIUM ON ADVANCES AND TRENDS IN STRUCTURES AND DYNAMICS
**October 22-25, 1984**
**Arlington, Virginia**

The George Washington University and NASA Langley Research Center are organizing a Symposium on Advances and Trends in Structures and Dynamics to be held October 22-25, 1984 at the Sheraton National Hotel, Arlington, Virginia.

Twenty-six sessions are planned which include: Trends in Computer Hardware, Expert Systems and Engineering Software, Interactive Computer Graphics and Computer-Aided Instruction, Parallel Numerical Algorithms and Their Implementation, Advances in Finite Element Technology, Seismic Analysis and Contact Problems, Mechanics of Materials, Inelasticity, Mesh Generation and Analysis of Large Systems, Random Motion and Dynamic Response, Impact and Penetration Mechanics, Damping and Control of Spacecraft Structures, Multidisciplinary and Interaction Problems, Structural and Dynamic Stability, Optimization, Composite Materials and Structures, and Computational Strategies for Nonlinear and Fracture Mechanics Problems. An evening tutorial session and a panel discussion are also planned with the theme: AI-Based Expert Systems, and Their Potential for Structures and Dynamics.

For further information contact: Prof. Ahmed K. Noor, Mail Stop 246, George Washington University, NASA Langley Research Center, Hampton, VA 23665 - (804) 865-2897.

# ADVANCE PROGRAM

# 55th SHOCK AND VIBRATION SYMPOSIUM

October 23-25, 1984

Dayton, Ohio

Host
Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

THE SHOCK AND VIBRATION
INFORMATION CENTER

# GENERAL INFORMATION

***CONFERENCE LOCATION:*** Registration, Information and Unclassified Technical Sessions are at the Stouffer's Dayton Plaza Hotel, Dayton, OH. Classified Sessions will be held at the Wright-Patterson Air Force Base (WPAFB), Dayton, OH. There is a separate program for the Classified Sessions.

***REGISTRATION:*** Registration fee covers the cost of the proceedings of the 55th Shock and Vibration Symposium. There is no fee for SVIC Annual Subscribers* or for participants. Since the registration fee covers only the cost of the proceedings, there will be no reduced fee for part time attendance. The schedule of fees is as follows:

Subscriber Registration (for employees of SVIC Annual Subscribers*) . . . . . . . . . No Fee

Participant Registration (Authors, Speakers, Chairmen, Cochairmen). . . . . . . No Fee

General Registration (All others) (Payable to Disbursing Officer, NRL) . . . $200.00

**On-Site Registration:** Pre-registrants may obtain their badges or last minute registration may be accomplished at the following times:

Stouffer's Dayton Plaza Hotel

| | |
|---|---|
| Monday, October 22 . . . . . | 7:00 p.m. - 9:00 p.m. |
| Tuesday, October 23 . . . . . | 7:30 a.m. - 4:00 p.m. |
| Wednesday, October 24 . . . | 8:00 a.m. - 4:00 p.m. |
| Thursday, October 25 . . . . | 8:00 a.m. - 2:00 p.m. |

***INFORMATION:*** The information and message center will be located in the registration area. The phone number of the hotel is (513) 224-0800. Telephone messages and special notices will be posted near the registration desk. All participants should check regularly for messages or timely announcements. Participants will not be paged in the session.

***COMMITTEE MEETINGS:*** Space is available to schedule meetings for special committees and working groups at the Symposium. To reserve space, contact SVIC. A schedule of special meetings will be posted on the Bulletin Board.

***SVIC STAFF:***

Dr. J. Gordan Showalter, Acting Director
Mr. Rudolph H. Volin
Mrs. Jessica P. Hileman
Mrs. Elizabeth McLaughlin
Mrs. Mary Gobbett

Shock and Vibration Information Center
Naval Research Laboratory, Code 5804
Washington, DC 20375

Telephone: (202) 767-2220
AUTOVON: 297-2220

***SUMMARIES OF PRESENTED PAPERS:*** These will be available to all attendees at the time of registration. These summaries are longer than the usual abstract and contain enough detail to evaluate their usefulness to you as an individual. By reading these in advance of the sessions, you may more effectively choose the papers you wish to hear.

***SHOCK AND VIBRATION BULLETIN No. 55:*** Papers presented at the 55th Symposium will, at the author's request, be reviewed and published in the Bulletin after approval by two reviewers. The discussion following these papers will be edited and published with the respective papers. Registrants who have paid the registration fee or have satisfied the registration requirements will receive a copy of the Bulletin. Additional sets of the 55th Bulletin will be sent to annual subscribers. Others may purchase the Bulletin from the Shock and Vibration Information Center. The price is $200.00 for each set delivered in the United States.

***OTHER PUBLICATIONS:*** Sample copies of current publications of the Shock and Vibration Information Center may be examined at the registration area. Order blanks are available for those wishing to use them.

****A SVIC Annual Subscriber is an organization that has purchased the SVIC Annual Subscription Service Package for Fiscal Year 1985 (1 October 1984 - 30 September 1985)***

## 55th SYMPOSIUM PROGRAM COMMITTEE

Mr. Brantley Hanks
Mail Stop 230
NASA Langley Research Center
Hampton, VA 23665

Mr. John Wafford
Aeronautical Systems Division
ASD/ENFSL
Wright-Patterson AFB, OH 45433

Mr. James Daniel
U.S. Army Missile Command
Test and Evaluation Directorate
DRSMI-RTR
Redstone Arsenal, AL 35898

Mr. David Hurt
Code 55X
Naval Sea Systems Command
Washington, DC 20362

Dr. Kent Goering
Defense Nuclear Agency
Washington, DC 20305

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**Tuesday, October 23** **Opening Session**
**8:30 a.m.** **Van Cleve I & II**

Chairman: (to be determined)

*Cochairman: (to be determined)*

This session is still being planned. Details will appear in the final program.

**Tuesday, October 23** **Session 1A**
**2:00 p.m.** **Van Cleve I**

**DYNAMIC TESTING**

Chairman: Mr. Edwin M. Rzepka, Naval Surface Weapons Center, Silver Spring, MD

Cochairman: Mr. James W. Daniel, U.S. Army Missile Command, Redstone Arsenal, AL

1. Three Axis Shaker System – W.D. EVERETT and T. HELFRICH, Pacific Missile Test Center, Point Mugu, CA

2. Initial Design and Evaluation of a Unique High Frequency Fatigue Test System -- D.I.G. JONES, Materials Laboratory, Wright-Patterson AFB, OH

3. Investigation of Modes, Frequencies and Forced Response of a High Frequency Fatigue Test System – D.K. RAO and D.I.G. JONES, Materials Laboratory, Wright-Patterson AFB, OH

4. Data Analysis Techniques to Support Structural Modeling -- J.W. JETER and P.H. MERRITT, Hughes Aircraft Company, Albuquerque, NM

5. Ultra High Velocity Impacts Utilizing Rocket Sleds and Explosively Accelerated Flyer Plates -- R.A. BENHAM, W.R. KAMPFE and D.L. PRESTON, Sandia National Laboratories, Albuquerque, NM

6. Water Impact Testing of a Filament Wound Case – D.A. KROSS and A.A. SCHMIDT, NASA Marshall Space Flight Center, Huntsville, AL, and R.T. KEEFE, Chrysler Corporation, New Orleans, LA

7. Structural Shock and Vibration from Ballistic Impact on Ceramic Armor -- R.S. BERTKE, D.L. PAISLEY, and S.J. BLESS, University of Dayton, Dayton, OH

**Tuesday, October 23** **Session 1B**
**2:00 p.m.** **Van Cleve II**

**FLUID-STRUCTURE INTERACTION**

Chairman: *(to be determined)*

Cochairman: (to be determined)

1. Structural Response of Panels Subjected to Shock Loading -- R. HOULSTON and J.E. SLATER, Defence Research Establishment Suffield, Ralston, Alberta, Canada

2. An Analysis of Explosion-Induced Bending Damage in Submerged Shell Targets – M. MOUSSOUROS, Naval Surface Weapons Center, Silver Spring, MD

3. Generalized Dynamic Analysis of Interactive Fluid-Structure Transient Response -- J.E. BOISVERT and B.E. SANDMAN, Naval Underwater Systems Center, Newport, RI

4. On the Field Experiences of Undex Testing for a Stiffened Flat Plate Model – T.R. RENTZ and Y.S. SHIN, Naval Postgraduate School, Monterey, CA

5. Flow Induced Jitter Forces in Cooled HEL Mirrors -- E. MOAS, JR., United Technologies Research Center, West Palm Beach, FL

6. SDOF MDOF Models of Offshore Lattice Towers -- A Critical Study of Their Effectiveness in Predicting Dynamic Response -- V.G. IDICHANDY, V.G. HARI and C. GANAPATHY, Indian Institute of Technology, Madras, India

**Wednesday, October 24** **Plenary A**
**8:30 a.m.** **Van Cleve I**

Chairman: (to be determined)

Speaker: Dr. Alan Burkhard, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH

Subject: CERT -- Where We Have Been – Where We Are Going

**Wednesday, October 24** **Session 2A**
**9:40 a.m.** **Van Cleve I**

**FLIGHT VEHICLE DYNAMICS**

Chairman: Mr. Joseph J. Popolo, Grumman Aerospace Corporation, Bethpage, NY

Cochairman: Mrs. Phyllis Bolds, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, OH

1. Invited Paper

2. Airworthiness Flight Test Program of an Aircraft Equipment Fairing -- V.R. MILLER, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, OH, and T.P. SEVERYN, 4950 Test Wing, Wright-Patterson AFB, OH

3. Vibration Parametric Study Air Armament Stores on Fixed Wing Aircraft -- D.P. RICHARDS and M.P. NEALE, Hunting Engineering Ltd., Ampthill, Bedfordshire, England

4. Realistic Whole Store Ground Testing for the External Flight Carriage Vibration Environment -- J. HOMFRAY, Cape Warwick Limited, Warwick, England

5. On the Design of Test Rigs Having Prescribed Dynamic Characteristics -- T.H. RICHARDS, J.E.T. PENNY and K.J. BUTLER, University of Aston, Birmingham, UK

6. An Update of Space Craft Environments Induced by Ground Transportation -- M.R. O'Connell, Jet Propulsion Laboratory, Pasadena, CA

**Wednesday, October 24** **Session 2B**
**9:40 a.m.** **Van Cleve II**

**DAMPING AND ISOLATION**

Chairman: Dr. John P. Henderson, Wright Aeronautical Laboratories, Wright-Patterson AFB, OH

Cochairman: (to be determined)

1. Designing a Mobile, Transportable, Survivable Communications System Utilizing Commercial Equipment – M. BAKER, Structural Dynamics Research Corporation, San Diego, CA

2. Design of a Shock Isolation System for Mobile Shelters Subject to Blast Overpressure -- C. FLANIGAN and C. ENGELHARDT, Structural Dynamics Research Corporation, San Diego, CA

3. Passive Load Control Dampers – D.M. ECKBLAD and P.J. SCHIRMER, Boeing Aerospace Company, Kent, WA

4. The Acoustic Damping Characteristics of a Randomly Excited Metal Plate Specimen in Air and Water Environments -- Y.S. SHIN, P.F. MILSTER and S.T. KNOUSE, Naval Postgraduate School, Monterey, CA

5. Vibration and Damping Analysis of Partially Covered Rectangular Sandwich Plate -- A.K. LALL, N.T. ASNANI and B.C. NAKRA, Indian Institute of Technology, Delhi, India

6. Vibration and Damping Analysis of Curved Sandwich Panels with Viscoelastic Core – J. VASWANI, N.T. ASNANI and B.C. NAKRA, Indian Institute of Technology, Delhi, India

**Wednesday, October 24** **Session 3A**
**2:00 p.m.** **Van Cleve I**

## SEISMIC LOADS

Chairman: (to be determined)

Cochairman: (to be determined)

1. Effects of Multiple Blast Loads on Structural Response – A. LONGINOW and J. MOHAMMADI, Illinois Institute of Technology, Chicago, IL, and A. WIEDERMANN, ATResearch Associates, Glen Ellyn, IL

2. Shock Environment in a Civil Defense Blast Shelter -- T.R. SLAWSON, S.C. WOODSON and S.A. KIGER, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

3. Earthquake Induced Motion Environments in Framed Buildings – A. LONGINOW, R.R. ROBINSON and J. MOHAMMADI, Illinois Institute of Technology, Chicago, IL

4. Development of a 3 Kilobar Static Calibration Device -- C.D. LITTLE, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

5. D'Alembert Unfolding of Hopkinson Bar Airblast Impulse Data -- C.R. WELCH and H.G. WHITE, U.S. Army Waterways Experiment Station, Vicksburg, MS

6. Results of High Pressure Static Evaluation Tests on Developmental Soil Gages in Sand and Clay -- A.P. OHRT, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

7. Design and Field Experience with the WES 10 KB Airblast and Stress Gages -- C.E. JOACHIM and C.R. WELCH, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

**Wednesday, October 24** **Session 3B**
**2:00 p.m.** **Van Cleve II**

## DAMPING PRACTICES

Chairman: Dr. Lynn Rogers, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, OH

Cochairman: Mr. Michael Parin, Anatrol Corporation, Cincinnati, OH

1. Spin Pit Test of Bladed Disk with Blade Platform Friction Dampers – R.J. DOMINIC, University of Dayton Research Institute, Dayton, OH

2. A Different View of Viscous Damping – P.J. TORVIK, Air Force Institute of Technology, Wright-Patterson AFB, OH and R. BAGLEY, 4950th Test Wing, Wright-Patterson AFB, OH

3. Finite Element Analysis of a Damped TF41-A100 First Stage Fan Blade to Prevent Flutter -- M.F. KLUESENER, University of Dayton Research Institute, Dayton, OH

4. Temperature Shift Effects on Complex Modulus -- J. EICHENLAUB, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, OH

5. *Passive Damping - Sonic Fatigue - and the KC135* – R. DOMINIC, M. BOUCHARD and M. DRAKE, University of Dayton Research Institute, Dayton, OH

6. Design of Integrally Damped Spacecraft Panels -- C.V. STAHLE and J.A. STALEY, General Electric Company, Philadelphia, PA

7. A Different Approach to Designed in Passive Damping -- M.L. DRAKE, University of Dayton Research Institute, Dayton, OH

8. Analysis of a Damped Space Tower -- C.W. WHITE and G. MOROSOW, Martin Marietta Corporation, Denver, CO

**Thursday, October 25** **Plenary B**
**8:30 a.m.** **Van Cleve I**

Chairman: Dr. Ronald L. Eshleman, Vibration Institute, Clarendon Hills, IL

Speaker: Dr. Neville F. Reiger, Stress Technology, Inc., Rochester, NY

Subject: Factors Affecting the Fatigue Life of Turbomachinery Blades and an Assessment of Their Accuracy

**Thursday, October 25** **Session 4A**
**9:40 a.m.** **Van Cleve I**

## MACHINERY DYNAMICS

Chairman: Dr. Ronald L. Eshleman, Vibration Institute, Clarendon Hills, IL

Cochairman: Mr. Paul Maedel, Westinghouse Corporation, Philadelphia, PA

1. An Integrated Gear System Dynamics Analysis at Low and High Frequency Ranges -- L.K.H. LU, W.B. ROCK-

WOOD and P.C. WARNER, Westinghouse Electric Corporation, Sunnyvale, CA, and R.G. DE JONG, Cambridge Collaborative, Cambridge, MA

2. Coupled Torsional-Flexural Vibration of a Geared Shaft System Using Finite Element Analysis -- S.V. NERIYA, R.B. BHAT and T.S. SANKAR, Concordia University, Montreal, Quebec, Canada

3. Vibration Analysis of a Rotating Turbine Blade -- J.K. LEE, A.W. LEISSA, and T.H. YOUNG, The Ohio State University, Columbus, OH

4. Finite Element Modelled Design of Lathe Spindles: The Static and Dynamic Analyses Using a Dynamic Condensation Technique -- V.R. REDDY and A.M. SHARAN, Memorial University of Newfoundland, St. John's, Newfoundland, Canada

5. Influence of an Axial Torque on the Dynamic Behavior of Rotors in Bending -- R. DUFOUR, J. DER HAGOPIAN and M. LALANNE, Institut National des Sciences Appliques de Lyon, Villeurbanne, France

6. Sensitivity Analysis of the Locations of the Balancing Planes of an Unbalanced Rotor-Bearing System Using Dynamic Condensation Technique -- S. AHUJA and A.M. SHARAN, Memorial University, St. John's, Newfoundland, Canada

**Thursday, October 25** **Session 4B**
**9:40 a.m.** **Van Cleve II**

### SYSTEM IDENTIFICATION

Chairman: (to be determined)

Cochairman: (to be determined)

1. Structural Damage Detection by the System Identification Technique -- J.C.S. YANG, T. TSAI, V. PAVLIN and W.H. TSAI, University of Maryland, College Park, MD

2. Time Domain Modal Analysis of a Slotted Cylindrical Shell -- W. FENG, P. ZHANG and T.C. HUANG, University of Wisconsin, Madison, WI

3. Multiple Input Excitation Using Burst Random -- D. HUNT, Structural Dynamics Research Corporation, San Diego, CA, and R. ZIMMERMAN, Quixote Measurement Dynamics, Inc., San Diego, CA

4. Application of the Ibrahim Time Domain Algorithm to Spacecraft Transient Responses -- R.R. KAUFFMAN, General Electric Company, Philadelphia, PA

5. Data Acquisition/Analysis/Storage Systems for Structural-Dynamic Testing Using a Distributed-Processing Architecture -- S. SMITH, E.S. OLSON and J.A. VINSON, Lockheed Palo Alto Research Laboratory, Palo Alto, CA, and G.J. CHAMBERS and M.J. McMAHON, Lockheed Missiles and Space Company, Sunnyvale, CA

6. The Identification Matrix and Convergence in Off-Line System Identification -- K. TOMITA and D. FROHRIB, University of Minnesota, Minneapolis, MN

**Thursday, October 25** **Session 5A**
**2:00 p.m.** **Van Cleve I**

### STRUCTURAL DYNAMICS

Chairman: Mr. Brantley R. Hanks, NASA Langley Research Center, Hampton, VA

Cochairman: Mr. Jess H. Jones, NASA Marshall Space Flight Center, Huntsville, Al

1. Dynamic Buckling of Radially Constrained Circular Ring -- R.W. WU, Lockheed Missiles and Space Company, Sunnyvale, CA

2. Model Evaluation of Spinal Injury Likelihood for Various Ejection System Parameter Variations -- E. PRIVITZER and M.M. HOFFMAN, Air Force Aerospace Medical Research Laboratory, Wright-Patterson AFB, OH

3. Periodic and Chaotic Motions of a Mass String System under Harmonic Load -- C.N. BAPAT and S. SANKAR, Concordia University, Montreal, Quebec, Canada

4. Free Vibration Studies of Corner Supported Rhombic, Laminated Composite Plates -- K. KAMAL, M.R. MOHAN and S. DURVASULA, Indian Institute of Science, Bangalore, India

5. Dynamics of Laminated Composites under Initial Stress -- M.C. DOKMECI, Istanbul Technical University, Istanbul, Turkey

6. Multi-Level Substructuring of Large Eigenproblems Using Quadratic Subspace Iteration -- R. RAJATABHOTHI, Chulalongkorn University, Bangkok, Thailand, and C.P. JOHNSON, The University of Texas, Austin, TX

**Thursday, October 25** **Session 5B**
**2:00 p.m.** **Van Cleve II**

### SHORT DISCUSSION TOPICS

Chairman: (to be determined)

Cochairman: (to be determined)

| **Friday, October 26** | **Technical Tour** |
|---|---|
| Depart Stouffer's Dayton Plaza Hotel | 9:00 a.m. |
| Return Stouffer's Dayton Plaza Hotel | 12:30 p.m. |

*Those interested in participating in the tour must sign up at* the registration desk by noon on Wednesday, October 24. Spouses are welcome.

# ABSTRACTS FROM THE CURRENT LITERATURE

## ABSTRACT CONTENTS

## AVAILABILITY OF PUBLICATIONS ABSTRACTED

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

***Periodical articles, society papers, and papers presented at conferences*** may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

***Government reports*** may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

***Ph.D. dissertations*** are identified by a DA order number and are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48108.

***U.S. patents and patent applications*** may be ordered by patent or patent application number from Commissioner of Patents, Washington, D.C. 20231.

***Chinese publications,*** identified by a CSTA order number, are available in Chinese or English translation from International Information Service, Ltd., P.O. Box 24683, ABD Post Office, Hong Kong.

When ordering, the pertinent order number should always be included, not the DIGEST abstract number.

A List of Periodicals Scanned is published in issues, 1, 6, and 12.

# MECHANICAL SYSTEMS

## ROTATING MACHINES

**84-1874**

**Helix and Felix: Loading Standards for Use in the Fatigue Evaluation of Helicopter Rotor Components**

A.A. Tenhave

National Aerospace Lab., Amsterdam, Netherlands, Rept. No. NLR-MP-82041-U, 24 pp (Aug 1982) N84-15149

Key Words: Fatigue tests, Helicopters, Rotors

Standardized fatigue test load histories for helicopter rotors are presented. Loading standards for fixed wing aircraft are described.

**84-1875**

**Analytical Study on Engine Noise Caused by Vibration of the Cylinder Block and Crankshaft**

T. Kubozuka, Y. Hayashi, Y. Hayakawa, and K. Kikuchi

Central Engrg. Labs., Nissan Motor Co., Ltd., SAE Paper No. 830346

Key Words: Crankshafts, Engine noise, Torsional vibrations, Resonant frequencies, Engine cylinder blocks

To clarify the mechanism of torsional and lateral bending of the cylinder block which has a large effect on engine noise, an analysis was conducted on the influence of crankshaft torsional vibration on cylinder block vibrations. Results show that the lateral forced vibration of the crankshaft by the fluctuation of the lateral inertia force, generated with the torsional vibration of the crankshaft, directly causes vibration of the cylinder block; the level of cylinder block vibration varies according to the condition in which the frequency of the fluctuation of inertia force approaches the resonant frequencies of the cylinder block.

**84-1876**

**Experiments on the Coupling and Transmission Behavior of Crankshaft Torsional Bending and Longitudinal Vibrations in High Speed Engines**

H. Okamura, K. Sogabe, Y. Sato, Y. Suzuki, and S. Arai

Sophia Univ., SAE Paper No. 830882

Key Words: Crankshafts, Coupled response, Torsional vibrations, Bending vibration, Longitudinal vibration

The coupling behavior of the torsional, bending, and longitudinal vibrations in the crankshaft is described. The incidental excitation forces under crankshaft torsional vibration due to reciprocating and rotating masses are derived theoretically. Experiments on the coupling behavior of the crankshaft vibrations and the excitation behavior in the engine structure were performed in a four-cylinder automotive engine; their results are discussed.

**84-1877**

**Load Torque Effects on the Critical Speeds of a Continuous Rotor**

R. Cohen and I. Porat

Technion-Israel Inst. of Technology, Haifa, Israel, J. Dynam. Syst., Meas. Control, Trans. ASME, 106 (1), pp 70-74 (Mar 1984) 6 figs, 1 table, 8 refs

Key Words: Shafts, Rotors, Critical Speeds, Torque

The influence of the load torque on the critical velocities of a shaft mounted on short bearings is dealt with. While in most works on this subject the load torque is taken as axial, it is shown here that, provided the external torque does not change its initial direction as the shaft is deformed and is applied through an ideal spherical coupling, the assumption of a semitangential mode is the correct one. Revised values of the critical torques and velocities are calculated accordingly and compared to those based on the conventional assumption.

**84-1878**

**Designing Vibrating Beams and Rotating Shafts for Maximum Difference Between Adjacent Natural Frequencies**

N. Olhoff and R. Parbery

Dept. of Solid Mechanics, The Technical Univ. of Denmark, Lyngby, Denmark, Intl. J. Solids Struc., 20 (1) pp 63-75 (1984) 6 figs, 2 tables, 9 refs

Key Words: Shafts, Beams, Cantilever beams, Natural frequencies

Using the cross-sectional area function as the design variable, we determine the optimal design of a transversely vibrating, thin, elastic beam or rotating shaft that maximizes the difference between two adjacent natural frequencies. The beams have geometrically similar cross-sections while the shafts are restricted to be circular, and a minimum constraint is prescribed for the cross-sectional area. The volume, length, and boundary conditions are assumed to be given, and the beams or shafts may be equipped with given, non-structural masses or disks.

## 84-1879

### Self-Excited Vibration in High-Performance Turbomachinery

F. Ehrich and D. Childs

General Electric Co., Lynn, MA, Mech. Engrg., 106 (5), pp 66-79 (May 1984) 15 figs, 3 tables, 38 refs

Key Words: Subsynchronous vibration, Turbomachinery

This article reviews both the known and unknown factors in unstable subsynchronous motion. It describes the differences and problems associated with stable and unstable motion, the characteristics of destabilizing rotor dynamics mechanism and the effects of rotor stiffness and increased external damping on unstable motion, and the expected frequency of unstable motion. It also discusses which elements in turbomachinery give rise to unstable motion and how they are modeled, what instrumentation and analysis tools are available, how to convert an unstable unit into a stable unit, and the prospects for the design of stable high performance machinery.

## 84-1880

### Distinction Between Different Types of Impeller and Diffuser Rotating Stall in a Centrifugal Compressor with Vaneless Diffuser

P. Frigne and R. Van Den Braembussche

Institut CERAC, CH-Ecublens, Belgium, J. Engrg. Gas Turbines Power, Trans. ASME, 106 (2), pp 468-474 (Apr 1984) 16 figs, 20 refs

Key Words: Compressors, Centrifugal compressors, Stalling

Results of an experimental investigation of the subsynchronous rotating flow patterns in a centrifugal compressor with vaneless diffuser are described. Several compressor configurations are examined by means of hot wire anemometry. Fourier analysis allowed one to distinguish between the different modes of unstable operation. For both impeller and diffuser rotating stall, comparison is made between the amplitude, frequency, and periodicity of the induced velocity fluctuations.

## 84-1881

### A Theory of Rotating Stall of Multistage Axial Compressors: Part I - Small Disturbances

F.K. Moore

Cornell Univ., Ithaca, NY 14853, J. Engrg. Gas Turbines Power, Trans. ASME, 106 (2), pp 313-320 (Apr 1984) 6 figs, 1 table, 12 refs

Key Words: Compressors, Stalling

An analysis is made of rotating stall in compressors of many stages, finding conditions under which a flow distortion can occur which is steady in a traveling reference frame, even though upstream total and downstream static pressure are constant. In the compressor, a pressure-rise hysteresis is assumed. Flow in entrance and exit ducts yield additional lags. These lags balance to give a formula for stall propagation speed.

## 84-1882

### A Theory of Rotating Stall of Multistage Axial Compressors: Part II - Finite Disturbances

F.K. Moore

Cornell Univ., Ithaca, NY 14853, J. Engrg. Gas Turbines Power, Trans. ASME, 106 (2), pp 321-326 (Apr 1984) 6 figs, 5 refs

Key Words: Compressors, Stalling

A small-disturbance theory of rotating stall in axial compressors is extended to finite amplitude, assuming the compressor characteristic is a parabola over the range of the disturbance. An exact solution is found which requires the operating point to be at the minimum or maximum of the parabola. If the characteristic is flat in a deep-stall regime, the previous harmonic solution applies with neither reverse flow or unstalling. If the characteristic is concave upward in deep stall, the disturbance has a skewed shape, steeper at the stall-zone trailing edge as experiment shows. Propagation speed is only slightly affected by this nonlinearity.

## 84-1883

### A Theory of Rotating Stall of Multistage Axial Compressors: Part III - Limit Cycles

F.K. Moore

Cornell Univ., Ithaca, NY 14853, J. Engrg. Gas Turbines Power, Trans. ASME, 106 (2), pp 327-336 (Apr 1984) 20 figs, 1 table, 6 refs

Key Words: Compressors, Stalling

A theory of rotating stall, based on single parameters for blade-passage lag and external-flow lag and a given compressor characteristic yields limit cycles in velocity space. These limit cycles are governed by Liénard's equation with the characteristic playing the role of nonlinear damping function. Cycle integrals of the solution determine stall propagation speed and the effect of rotating stall on average performance. Solution with various line-segment characteristics and various throttle settings are found and discussed.

**84-1884**

**Introduction to Dynamics of Rotating Machine Aggregates**

V. Oravský

Institute of Materials and Mechanics of Machines of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 139-151 (1984) 3 figs, 12 refs

(In Slovak)

Key Words: Rotating machinery

Main parts of aggregates are described, classification and the present state of problems in dynamics of aggregates are given. A concept of the basic aggregate is introduced. Then equations of an aggregate with variable moment of inertia, variable load and dynamic drive characteristic are stated.

**84-1885**

**A Contribution to Dynamics of Machine Aggregates with an Asynchronous Drive**

V. Oravský and J. Mudrik

Institute of Materials and Mechanics of Machines of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 153-167 (1984) 5 figs, 9 refs

(In Slovak)

Key Words: Rotating machinery, Asynchronous motors

The steady-state motion of a machine aggregate consisting of a crank-slider mechanism and asynchronous motor is investigated. Characteristics of a nonlinear and linear dynamical motor are taken into account and results are compared and analyzed. The problem is solved analytically on an analog computer.

**84-1886**

**Automatic Design of Shafts**

A. Gulbinas, M. Bogdevičius, and M. Kubilienė

Vilnius Civil Engrg. Inst., Vilnius, Lithuanian SSR, Dynamics and Strength of Machinery and Structures. Collection of Articles in Mechanics No. 25. Vilnius Civil Engrg. Inst., Vilnius, Lithuanian SSR, 1983, pp 136-145, 1 fig, 4 refs

(In Russian)

Key Words: Shafts, Fatigue life, Finite element technique, Design techniques

The finite element method is used for the automatic design of shafts considering statical strength and fatigue. Automatic selection of the type and parameters of rolling bearings is included.

**84-1887**

**Critical Speed of Centrifugal Pumps**

S. Gopalakrishnan and Y. Usui

Byron Jackson Pump Div., Borg-Warner Corp., 5800 S. Eastern Ave., City of Commerce, CA, Shock Vib. Dig., 16 (4), pp 3-10 (Apr 1984) 58 refs

Key Words: Pumps, Centrifugal pumps, Critical speeds

Until recently critical speed calculations of pumps were made without considering the rotor dynamic effects of close clearance running fits. Publications in the last few years have made it clear that these effects must be considered in order to make the computations relevant to pump operation. This paper is a review of methods available for calculating critical speeds of pumps including rotor dynamic effects.

**84-1888**

**Dynamic Response of Rotating Beams with Nonconstant Angular Velocity**

D.C. Kammer

Ph.D. Thesis, Univ. of Wisconsin-Madison, 222 pp (1983)
DA8321758

Key Words: Beams, Angular speed

This investigation examines the effects of a nonconstant angular velocity upon the vibration of a rotating beam. It is assumed that the angular velocity can be written as the sum of a steady state value and a small periodic perturbation. The time dependence of the angular velocity results in the appearance of terms in the equations of motion which cause the system to be nonautonomous. The configuration studied consists of a beam mounted on the periphery of a rigid rotating body, and inclined at an arbitrary angle of tilt with respect to the spin axis. Two specific orientations, a radially mounted beam and a beam mounted parallel to the spin axis, are considered in the analysis. A perturbation technique, called the KBM method, is used to derive approximate solutions and the expressions for the boundaries between stable and unstable motion.

**84-1889**
**Effects of Different Rub Models on Simulated Rotor Dynamics**
A.F. Kascak and J.J. Tomko
NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. E-1801, NASA-TP-2220, 12 pp (Feb 1984)
N84-17590

Key Words: Rotors, Computer programs, Transient response

Using a direct integration, transient response rotor dynamics computer code, the response of turbine engine rotors to two different blade tip - seal interference rub models was studied. The first model, an abradable seal rub model, is based on an energy-loss-per-unit-volume theory (applicable to a ceramic turbine blade tip seal). The second, a smearin model, is based on viscous hydrodynamic theory (applicable to a metallic blade tip seal). The results from these two models were compared with those from a previously studied model based on dry friction theory.

**84-1890**
**Effects of Damping and Circulatory Forces on Dynamic Instability of Gyroscopic Conservative Continuous Systems**
R.C. Shieh
MRJ, Inc., Fairfax, VA 22030, J. Struc. Mech., 11 (2), pp 197-213 (1983) 2 figs, 14 refs

Key Words: Rotors, Damping effects, Gyroscopic effects

The title problem is studied, with emphasis on the small damping and circulatory force case. It is shown that small internal and/or external damping forces and/or small (as well as large) circulatory forces in general destabilize an otherwise stable gyroscopic conservative system. A condition for no destabilizing effects of these small forces is obtained. A concept of perfect system in elastic stability of nonconservative problems is also presented. An example problem is given for demonstration purposes.

**84-1891**
**Fan Pump Pressure Pulsation Field Measurement and Comparison with Factory Test Data**
C.P. Hamkins and J. A. Lorenc
Goulds Pumps, Inc., 240 Fall St., Seneca Falls, NY 13148, Tappi J., 67 (3), pp 74-77 (Mar 1984) 9 figs, 10 refs

Key Words: Pumps, Rotary pumps, Real time spectrum analyzers

Pressure pulsation data were taken for fan pumps during mill operation. The data are analyzed with a real time analyzer and are compared with factory tests of the same units prior to shipment. Although there are differences in the results, there is generally attenuation of the pulsations in final installations. Several mechanisms for the attenuation are postulated. The instrumentation and experimental techniques are explained.

**84-1892**
**Measurement of Relative Vibratory Motion at the Shroud Interfaces of a Fan**
A.V. Srinivasan and D.G. Cutts
United Technologies Res. Ctr., East Hartford, CT, J. Vib., Acoust., Stress, Rel. Des., Trans. ASME, 106 (2), pp 189-197 (Apr 1984) 21 figs, 3 refs

Key Words: Fans, Shrouds, Vibration measurement

Measurement results of steady as well as vibratory motions at ten successive shroud interfaces of a part-span shrouded fan, a 40-bladed-disk assembly designated as the R-80 fan are presented. These were extremely small motions taking place at mating shroud interfaces in the fan assembly.

**84-1893**

**A Study of Unsteady Pressures Near the Tip of a Transonic Fan in Unstalled Supersonic Flutter**

D.G. Halliwell, S.G. Newton, and K.S. Lit

Rolls-Royce Ltd., Derby, UK, J. Vib., Acoust., Stress, Rel. Des., Trans. ASME, 106 (2), pp 198-203 (Apr 1984) 13 figs, 9 refs

Key Words: Fans, Flutter

A comparison of experimental and theoretical results is presented for a modern transonic research fan vibrating in a coupled flutter mode. The measurement of steady and unsteady pressures on the aerofoil surface is described, as is the derivation of the accompanying blade motion using casing-mounted frequency modulated grids. This complex motion is used to calculate unsteady pressures from various unsteady aerodynamic theories. These theoretical models are reviewed and compared with the experimental data at a reference blade section.

**84-1894**

**Coupling Technique of Rotor-Fuselage Dynamic Analysis**

D.M. Tang and M.Q. Wang

Nanjing Aeronautical Inst., Nanjing, China, J. Vib., Acoust., Stress, Rel. Des., Trans. ASME, 106 (2), pp 235-238 (Apr 1984) 6 figs, 2 tables, 5 refs

Key Words: Helicopters, Rotors, Impedance matching technique

The impedance matching technique is used for the dynamic analysis of the helicopter rotor coupled with fuselage in the rotating plane. The method is used to determine the inplane rotor-fuselage dynamic properties of a light helicopter with fiberglass-reinforced plastics rotor blades. Particular reference is given to the effect of anisotropic dynamic stiffness of the rotor shaft end of the fuselage on natural dynamic characteristics.

**84-1895**

**A Rapid Approach for Calculating the Damped Eigenvalues of a Gas Turbine on a Minicomputer: Theory**

E.J. Gunter, R.R. Humphris, and H. Springer

Rotor Dynamics Lab., Univ. of Virginia, Charlottesville, VA 22901, J. Vib., Acoust., Stress, Rel. Des., Trans. ASME, 106 (2), pp 239-250 (Apr 1984) 7 figs, 6 tables, 18 refs

Key Words: Gas turbines, Damped modes, Eigenvalue problems

The calculation of the damped eigenvalues of a large multistation gas turbine by the complex matrix transfer procedure may encounter numerical difficulties, even on a large computer due to numerical round-off errors. A procedure is presented in which the damped eigenvalues may be rapidly and accurately calculated on a minicomputer with accuracy which rivals that of a mainframe computer using the matrix transfer method. The method presented is based upon the use of constrained normal modes plus the rigid body modes in order to generate the characteristic polynomial of the system. The constrained undamped modes, using the matrix transfer process with scaling, may be very accurately calculated for a multistation turbine on a minicomputer. A five station rotor is evaluated to demonstrate the procedure. A method is presented in which the characteristic polynomial may be automatically generated by Leverrier's algorithm. The characteristic polynomial may be directly solved or the coefficients of the polynomial may be examined by the Routh criteria to determine stability. The method is accurate and easy to implement on a 16 bit minicomputer.

## RECIPROCATING MACHINES

**84-1896**

**Determination of the Sound Transmission Rate of Diesel Engines by Means of Cyclic Fluctuations**

K. Schmillen, A. Flotho, and W. Schlunder

Forschungsgesellschaft f. Energietechnik und Verbrennungs-motoren, Aachen, W. Germany, SAE Paper No. 831331

Key Words: Diesel engines, Sound transmission

The pressure time history in the combustion chamber of an IC-engine is seen as a sound phenomenon which, attenuated by the engine structure, is radiated as combustion noise. A distinction has been made between the direct and indirect combustion noise. The transmission rate/direct combustion noise has been investigated by the example of an air-cooled single cylinder diesel engine. Short-range noise intensity measurements as well as cylinder pressure measurements at several points in the combustion chamber have been carried out simultaneously.

**84-1897**

**Identification of Internal Noise Sources in Diesel Engines**

Y. Yawata and M.J. Crocker

Komatsu Ltd., Japan, SAE Paper No. 831330

Key Words: Diesel engines, Interior noise, Noise source identification

In order to identify noise sources in a diesel engine, specifically exciting forces such as combustion and piston slap, the so-called coherence method which utilizes relationships between the auto and cross spectra of cylinder pressure, cylinder liner acceleration and engine noise has been examined. Also, as an alternative, a multivariable regression analysis in one-third octave band auto spectra of each signal mentioned above has been made.

**84-1898**

**Noise and Vibration Reduction Measures Applied to Diesel Engine Cars**

K. Nishioka, H. Takada, and T. Kitahara

Isuzu Motors Ltd., Japan, SAE Paper No. 830925 (P-139)

Key Words: Diesel engines, Automobiles, Noise reduction, Vibration control

Some instances of the corrective activities concerning the noise and vibration problems such as idle noise, idle shake, driveline rattle, intake noise and booming noise experienced in the development stage of new diesel engine passenger cars are introduced here.

**84-1899**

**Diesel Engine Noise Reduction by the Use of a Reinforced Nylon Rocker Cover**

M. Tesio, G. Turino, and J.L. Chruma

Fiat Centro Ricerche, Torino, Italy, SAE Paper No. 830978

Key Words: Motor vehicle noise, Diesel engines, Engine noise, Noise reduction

In recent years the development of sophisticated engineering resins for the automotive industry has expanded the applications into areas generally reserved for metals. Weight and cost reduction have been driving forces for most conversions, with noise reduction only a distant possibility. This study describes work in which a thermoplastic nylon 66 rocker cover was designed to reduce the overall noise emitting from a diesel passenger car engine. A 10% reduction of engine acoustic power output was achieved.

**84-1900**

**Piston Slap Motion and Engine Noise under Low Temperature Idling Operation of Diesel Engines**

S. Furuhama and K. Hirukawa

Musashi Inst. of Tech., Japan, SAE Paper No. 830066

Key Words: Diesel engines, Engine noise

Diesel engines make a shrill noise called "idle knock" under low temperature idling operation. This causes a serious noise pollution problem in automobile diesel engines. It was clarified by this study that one important source of this noise was piston slap impulse. Piston slap motion was measured under usual operating conditions and a condition with additional oil supplied into the piston clearance. The piston slap motion was calculated, taking into account the frictional resistances of the crank mechanism and squeeze action of oil film.

## POWER TRANSMISSION SYSTEMS

**84-1901**

**A Study of the Torsional Vibration of Automotive Power Trains**

Wu Hei-Le, Shao Cheng, and Feng Zhen-Dong

Jilin Univ. of Tech., People's Rep. of China, SAE Paper No. 830881 (P-139)

Key Words: Power transmission systems, Torsional vibration, Damping effects

Experimental and theoretical research on the torsional vibration of automotive power trains is presented. A dynamic model for power trains was developed, and all parameters of the model were evaluated with experimental data. Free and forced torsional vibration calculations were performed. Spectrum analyses were used in data processing.

# STRUCTURAL SYSTEMS

## BRIDGES

**84-1902**

**Concrete Bridges Subjected to Impulsive Loading from Fuel-Air Explosives**

B. Hobbs

Univ. of Sheffield, Mappin St., Sheffield, S1 3JD, UK, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 2, pp 139-144, 5 figs, 2 tables, 17 refs

Key Words: Bridges, Concretes, Impulse response, Explosion effects

This paper is concerned with an analytical study of the effect of distributed impulsive loading on a range of concrete bridge types. The principal area of interest is collapse behavior and the establishment of criteria for effective demolition by means of fuel-air explosives. The basis of a simplified analytical approach developed for this work is outlined. Existing data from tests on small scale metal beams is used to assess the accuracy of the analytical method. Analytical results relating the expected permanent midspan deflection to the total impulse delivered by the explosion are presented.

## BUILDINGS

**84-1903**
**Elastic Analysis of the Imperial County Services Building**
G.C. Pardoen, P.J. Moss, and A.J. Carr
Dept. of Civil Engrg., Univ. of California, Irvine, CA 92717, Bull. Seismological Soc. Amer., 73A (6), pp 1903-1916 (Dec 1983) 7 figs, 5 tables, 12 refs

Key Words: Buildings, Seismic response, Elastic analysis, Experimental data

Results of an elastic structural analysis of a county services building in California are presented. This analysis is of particular significance because the building suffered major structural damage during the October 1979 Imperial Valley earthquake, and the building's response was recorded on permanently installed strong motion accelerographs.

**84-1904**
**Ambient Vibration Test Results of the Imperial County Services Building**
G.C. Pardoen
Dept. of Civil Engrg., Univ. of California, Irvine, CA 92717, Bull. Seismological Soc. Amer., 73A (6), pp 1895-1902 (Dec 1983) 6 figs, 3 tables, 11 refs

Key Words: Buildings, Vibration tests, Seismic response, Experimental data

The ambient vibration test results conducted on a county services building prior to the October 1979 Imperial Valley earthquake are summarized. These results are of significant interest because the building has been the source of many postearthquake investigations due to the fact that the 1979 earthquake represented the first time a building instrumented with strong motion recorders suffered and recorded the major structural failure.

## TOWERS

(See No. 1914)

## FOUNDATIONS

(Also see No. 1888)

**84-1905**
**Foundation Effects in Rotor Dynamic Behaviour**
G. Diana
Politecnico of Milan, Milan, Italy, Intl. Fed. of Theory of Machines and Mechanisms, 6th Congress, Tech. Committee on Rotordynamics Session Proc., Indian Inst. of Tech., New Delhi, India, Dec 19, 1983, pp 21-29, 10 figs, 23 refs

Key Words: Interaction: rotor-foundation, Machine foundations, Vibrating foundations

The interaction between the rotor and the supporting structure (foundation) plays an important role in rotor dynamics. From this point of view two effects can be considered. The first one is connected with the dynamic response of the foundation strongly affecting the resonant conditions of the rotor system as well as the dynamic behavior. The second one is connected with the quasi-static movement of the foundation due to different causes, such as thermal distortion, terrain creep, etc.

**84-1906**
**Testing, Modelling, and Applications of Interface Behavior in Dynamic Soil-Structure Interaction**
E.C. Drumm
Ph.D. Thesis, Univ. of Arizona, 323 pp (1983)
DA8401259

Key Words: Interaction: soil-structure, Sand, Concretes, Cyclic loading

The behavior of the interface between dry Ottawa sand and concrete has been studied using a new device developed for the cyclic testing of interfaces and joints. The stress conditions existing in the test device are investigated using stress cell measurements and a two-dimensional finite element analysis. A series of cyclic displacement-controlled interface tests are described in which the behavior of the interface is found to be a function of the applied normal stress, the amplitude of the applied displacement, the density of the sand, and the number of applied loading cycles. The (secant) shear stiffness is shown to increase with number of loading cycles, corresponding to an increase in sand density.

## UNDERGROUND STRUCTURES

**84-1907**

**Analysis of Buried Reinforced Concrete Arch Structures under Dynamic Loads**

H.E. Auld and W.C. Dass

*Applied Research Associates, Inc., Albuquerque, NM,* Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 119-123, 5 figs, 1 table, 7 refs

Key Words: Underground structures, Arches, Reinforced concrete, Single degree of freedom systems, Aerial explosions

A damped single degree-of-freedom model was developed to represent the gross dynamic behavior of shallow buried reinforced concrete arches subjected to specified nonuniform pressure distributions. Structural parameters were developed for a generic structure based upon available information in the literature and first principal calculations. Values of maximum crown deflection, calculated from numerical integration of the differential equation of motion, were compared with similar results from field experiments.

**84-1908**

**Response of Buried Concrete Structures to Buried High Explosive Charges; A Review in Similitude Format**

J.S. O'Brasky

Naval Surface Weapons Ctr., Weapons Development Branch, Dahlgren, VA, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 2, pp 110-115, 4 figs, 3 tables, 4 refs

Key Words: Underground structures, Concretes, Underground explosions, Experimental data

The results of some 250 experiments conducted since 1942 are reviewed and analyzed using nondimensional techniques. Data is in chart format for the most significant variables.

**84-1909**

**Today's Constraints Drive Ammo Magazines Underground**

W.A. Keenan and J.E. Tancreto

Naval Civil Engrg. Lab., Port Hueneme, CA, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 165-171, 8 figs, 4 refs

*Key Words: Underground structures, Ammunition, Storage*

Aboveground magazines for storage of ammunition are increasingly difficult to accommodate within constraints imposed by explosives safety, physical security, survivability, and fleet operational requirements. The Navy has developed an alternative design concept, called a chimney magazine. The chimney magazine consists of a box for weapons storage, two chimneys for access to storage, a horizontal sliding door over each chimney, a blanket of soil over the box, and a straddle trailer to retrieve and transport weapons. The concept dramatically increases the physical security and survivability of storage and dramatically decreases the encumbered land area without compromising explosives safety requirements for noncommunication of explosions, damage to storage from explosions, and protection of life and property in inhabited areas from blast, ground shock, and debris.

## ROADS AND TRACKS

**84-1910**

**Impact and Penetration of Layered Pavement Systems**

T.E. Bretz, Jr. and P.T. Nash

Air Force Engrg. and Services Ctr., Tyndall Air Force Base, FL, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 2, pp 30-34, 5 figs, 6 refs

Key Words: Pavements, Runways, Blast resistant structures, Penetration

The Air Force is sponsoring research on damage-resistant runway designs. The designs are based upon principles which use high strength/high density materials to resist weapon momentum. Initially, two subscale pavement sections will be designed, one representing a rigid pavement for long-term aircraft traffic, and the other representing a redundant surface to withstand limited aircraft operations. The penetration resistance for both pavement sections will be determined experimentally.

## CONSTRUCTION EQUIPMENT

**84-1911**

**Design of the Vibration Control Structure of a Tractor Seat**

I. Rurik

Inst. of Materials and Machine Mechanics of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 169-178 (1984) 5 figs, 5 refs

(In Slovak)

Key Words: Tractors, Seats, Vibration control

The paper discusses the problem of making the tractor driver's protection against vibrations under the working modes of the tractor Z 140 45 more effective by applying a passive vibration control structure of the seat. The problem is handled for vibrations acting upon the tractor driver in a vertical direction.

## POWER PLANTS

(See No. 2086)

## OFF-SHORE STRUCTURES

(Also see No. 2099)

**84-1912**

**Turbulent Wind and Tension Leg Platform Surge**

E. Simiu and S.D. Leigh

National Bureau of Standards, U.S. Dept. of Commerce, Washington, DC 20234, ASCE J. Struc. Engrg., 110 (4), pp 785-802 (Apr 1984) 4 figs, 3 tables, 30 refs

Key Words: Drilling platforms, Off-shore structures, Wind-induced excitation

A procedure is presented for estimating surge response to turbulent wind in the presence of current and waves. The procedure accounts for the nonlinearity of the hydrodynamic forces with respect to surge and for the coupling of aerodynamic and hydrodynamic effects. It is shown that current wind spectra do not model correctly the wind speed fluctuations at very low frequencies and an alternative model of the wind spectrum, whose ordinate at the origin is consistent with fundamental principles, is presented.

**84-1913**

**Dynamic Interactions Between Floating Ice and Offshore Structures**

P. Croteau

Ph.D. Thesis, Univ. of California, Berkeley, 355 pp (1983)

DA8328836

Key Words: Off-shore structures, Drilling platforms, Floating ice

Development of oil and gas resources at arctic and subarctic latitudes requires engineers to carefully consider the action of ice in designing offshore facilities for these areas. In this study, the interactions between an offshore structure and floating ice are investigated. Attention is directed to the case where ice fails by crushing at the face of the structure. A formulation suitable for investigating the dynamic response of platform systems with surrounding floating ice sheets or ice features is developed and applied.

**84-1914**

**Stiffness and Energy Dissipation Characteristics of Guyed Tower with Dynamic Mooring Properties**

D.G. Morrison

Univ. of Stellenbosch, Stellenbosch 7600, Rep. of South Africa, J. Energy Resources Tech., Trans. ASME, 106 (1), pp 18-23 (Mar 1984) 11 figs, 12 refs

Key Words: Towers, Guyed structures, Off-shore structures, Wave forces, Hysteretic damping

A simple model for a complex system is presented that contains the essential properties of the guyed tower. The dynamic response to wave load of a guyed tower is represented by a single degree of freedom model. Tower response, with different wave heights and hydrodynamic coefficients, using statically and dynamically determined mooring properties were calculated for a specific tower in 1100 ft (335 m) of water.

**84-1915**
**Structural Response Analysis of Tension Leg Platforms**
K. Yoshida, M. Ozaki, and N. Oka
Hiroshima Technical Inst., Mitsubishi Heavy Industries, Ltd., Hiroshima, Japan, J. Energy Resources Tech., Trans. ASME, 106 (1), pp 10-16 (Mar 1984) 12 figs, 11 refs

Key Words: Off-shore structures, Wave forces

A linear response analysis method of the tension leg platform (TLP) subjected to regular waves is proposed. In this analysis method, flexibility of the superstructure can be taken into account in the equations of motion; response motions, tension variations of tendons and structural member forces are solved simultaneously. The applicability of this method is confirmed by comparison with the test results on two kinds of small-scale TLP models. The structural responses obtained from these calculations and their effects on tension variation of tendons are studied.

# VEHICLE SYSTEMS

## GROUND VEHICLES

(Also see Nos. 1898, 2113, 2114, 2115, 2116, 2117)

**84-1916**
**Computer Aided Design Analysis of Instrument Panel Impact Zone**
E.B. Skuta
Chrysler Corp., SAE Paper No. 830260

*Key Words: Collision research (automotive)*

In anticipation of complying with European standards for impact protection, an instrument panel design was analyzed to determine impact zone boundaries and impact test velocities for the head of a front seat passengers. Chrysler computer aided design surfacing capabilities were utilized in the solution. Early knowledge of impact zone location is important to intelligent design decisions; knowledge of impact velocities aids in performing compliance testing.

**84-1917**
**Impact Analysis of Two-Vehicle Collisions**
R.M. Brach
Dept. of Aerospace and Mech. Engrg., Univ. of Notre Dame, Notre Dame, IN, SAE Paper No. 830468

Key Words: Collision research (automotive), Impact response

Twelve staged collisions were conducted with the purpose of furnishing collision data for use with accident models. In this paper the data is fit to a two-vehicle impact model using the method of least squares. The model is based upon the equations of impulse and momentum; the computed constants are the coefficients of restitution and equivalent coefficient of friction. A gradient search technique was used to minimize the sum of squares directly.

**84-1918**
**A Global Approach to Child Restraint Systems**
T. Turbell and B. Aldman
National Swedish Road and Traffic Res. Inst., Sweden, SAE Paper No. 831605 (P-134)

Key Words: Safety restraint systems

The present situation with regard to child restraints in Sweden is described. The concept of having small children travelling in rearward facing child seats in the front seat of the car is discussed, based on 15 years experience of these systems in use. The development of a special booster seat for handicapped children as well as the present situation on the European legislative work are also reported.

**84-1919**
**Protection for 5-12 Year Old Children**
J.B. Morris
Office of Vehicle Res., National Highway Traffic Safety Admn., SAE Paper No. 831654 (P-135)

Key Words: Collision research (automotive), Safety restraint systems

This paper addresses the question of what type of occupant restraints may be appropriate for 5-12 year old children in view of general concerns about the fit of safety belts. The paper analyzes the accident experience of these children as car passengers in comparison with that of passengers in all age brackets. Based on the analyses of the accident data guidelines are recommended for the 5-12 year old child.

## 84-1920

### Application of Acoustic Intensity Measurement to High Frequency Interior Noise

S. Hata, M. Takahashi, N. Utsunomiya, and H. Sakata
Tech. Development Div., Toyo Kogyo Co., Ltd., SAE Paper No. 830342

Key Words: Automobile noise, Interior noise, Acoustic intensity method

The application of an acoustic intensity measurement method to high-frequency interior noise is described. Technical problems in applying an averaging technique via surface scanning to high-frequency interior noise were conquered, and detailed quantitative contribution analysis of interior surfaces was made possible. Based on the analysis of a small passenger car, the effectiveness of additional noise control treatment can be roughly estimated, and an acoustic comfort of the car was improved by a minimum additional treatment required.

## 84-1921

### Computer Aided Analysis System for Noise and Vibration on Vehicles

K. Kanamaru, T. Kunieda, and K. Eishima
Toyota Motor Corp., SAE Paper No. 830344

Key Words: Ground vehicles, Vibration analysis, Noise analyzers

An analysis system for vehicle noise and vibration has been developed. It consists of a minicomputer based analog processing system connected with a large main-frame computer. This system features multi-modes for data analysis, fast data processing, data compatibility with conventional analog systems and feasibility. Fast data processing was achieved by newly developed FFT processor and minicomputer software.

## 84-1922

### Sound Intensity Measurements in Passenger Compartments (Schallintensitätsmessungen im Innenraum von Kraftfahrzeugen)

H. Kutter, H. Gese, and W. Ecker
Dorfstr. 77, 3004 Isernhagen 2, Automobiltech. Z., 86 (1), pp 25-28 (Jan 1984) 4 figs, 3 refs
(In German)

Key Words: Automobiles, Sound intensity, Measurement techniques, Motor vehicle noise, Interior noise

The sound generated in the passenger compartments of automobiles is an essential criterion of driving comfort. The localization of contributing sound sources often causes problems because it is not possible to determine the direction of sound flow with conventional sound-measuring techniques. The intensity measurement technique can help overcome these problems, even in the very complicated sound fields found in automobiles. Using this technique it is possible to follow the essential sound flows right up to the surfaces of radiating areas. The features making an intensity instrument suitable for measurements in passenger compartments are described along with practical handling hints.

## 84-1923

### Freight Car Lateral Dynamics -- An Asymptotic Sketch

A.M. Whitman and A.-R.M. Khaskia
Tel-Aviv Univ., Tel-Aviv, Israel, J. Dynam. Syst., Meas. Control, Trans. ASME, 106 (1), pp 107-113 (Mar 1984) 5 figs, 15 refs

Key Words: Freight cars, Critical speeds, Asymptotic approximation

A model of a freight car is analyzed using asymptotic methods and a formula is obtained for the critical speed that is valid over a wide range of warp stiffnesses. Corrections to this formula are discussed that are engendered by the other parameters that influence the motion. The results of the analysis are compared with numerical solutions of the model in order to assess their accuracy.

## 84-1924

### Development of Aerodynamic Computation Routine for Road Vehicles Using Panel Method

H. Djojodihardjo
Inst. of Tech. Bandung & National Inst. of Aeronautics and Space, Indonesia, SAE Paper No. 830891 (P-139)

Key Words: Ground vehicles, Aerodynamic loads

A numerical method for the calculation of pressure distribution on automobile bodies is developed, utilizing panel approach already established in the literature. In the present phase, by resort to Green's identity, the road vehicle body is represented by doublet singularities. Attention is given to the modeling of the wake shed off the aft part of the body. The plausibility of the method is investigated by application to simple geometries. Preliminary results indicate that the method can predict the velocity potential with reasonable accuracy, but further refinement is required to predict surface pressure distribution accurately.

## SHIPS

**84-1925**

**Nonlinear Springing of a Ship in Irregular Head Seas**

S. Slocum

Ph.D. Thesis, The Univ. of Michigan, 239 pp (1983) DA8401775

Key Words: Ships, Flexural vibration, Fluid-induced excitation

Fluid forces which excite a vertical two-node flexural vibration of a ship in forward motion in irregular head seas are considered. Nonlinear sum frequency flow interactions, which often induce a vibration at the ship's resonant response frequency, are investigated through analytical and experimental studies. Results of extensive model test experiments are presented and discussed. The experiments include investigations of the sensitivity of the nonlinear component of the flexural vibration to wave frequency, wave amplitude, ship speed, structural stiffness, and motions in the heave and pitch modes.

## AIRCRAFT

(Also see Nos. 1874, 1894, 1976, 1977, 2087)

**84-1926**

**Comparison of Model Helicopter Rotor Primary and Secondary Blade/Vortex Interaction Blade Slap**

J.E. Hubbard, Jr. and K.P. Leighton

Massachusetts Inst. of Tech., Cambridge, MA, J. Aircraft, 21 (5), pp 346-350 (May 1984) 9 figs, 14 refs

Key Words: Helicopter noise

A study of the relative importance of blade/vortex interactions which occur on the retreating side of a model helicopter rotor disk is described. Some of the salient characteristics of this phenomenon are presented and discussed. It is shown that the resulting secondary blade slap may be of equal or greater intensity than the advancing side (primary) blade slap. Instrumented model helicopter rotor data are presented which reveal the nature of the retreating blade/vortex interaction.

**84-1927**

**Helicopter Noise Certification and Sensitivity Studies Along the Procedural Lines of the New ICAO Annex 16/Chapter 8 Regulations**

W. Splettstösser, H. Heller, and V. Klöppel

Deutsche Forschung- und Versuchsanstalt f. Luft- und Raumfahrt, Forschungzentrum Braunschweig, Abteilung Technische Akustik, Bienroder Weg 53, 3300 Braunschweig, Fed. Rep. Germany, Vertica, 8 (1), pp 27-38 (1984) 10 figs, 5 tables, 1 ref

Key Words: Helicopter noise, Standards and codes

This paper discusses the noise-measurement experience gained in the application of the new International Civil Aviation Organization (ICAO) Annex 16/Chapter 8 helicopter noise certification Standard as well as results from recent noise sensitivity studies on two modern-design helicopters. The measurement procedure, the data acquisition and reduction as well as the applied correction procedures are briefly described.

**84-1928**

**Practical Computation of Unsteady Lift**

T.S. Beddoes

Westland Helicopters Ltd., Yeovil, Somerset BA20 2YB, UK, Vertica, 8 (1), pp 55-71 (1984) 11 figs, 13 refs

Key Words: Rotors, Aerodynamic loads, Helicopters

The requirements for the computation of 2D unsteady lift within the context of rotor airloads and performance calculation are shown to be fulfilled by an indicial formulation. It is shown how the indicial formulation may be expanded to provide a more general form of lift transfer function which may be used to evaluate explicitly the response to idealized forcing such as the frequency response and ramp motion. Results from the application of recent developments in the computation of unsteady transonic flow are used to define the indicial lift function which is generalized in an appropriate form for rotor applications and evaluated for idealized forcing.

**84-1929**

**Evaluation of the Acoustic Intensity Approach to Identify Transmission Paths in Aircraft Structures**

M.J. Crocker, K.E. Heitman, and Y.S. Wang

School of Mech. Engrg., Purdue Univ., Lafayette, IN, SAE Paper No. 830734

Key Words: Aircraft noise, Interior noise, Sound transmission

The new two-microphone acoustic intensity technique has been applied to the determination of the transmission paths of sound into an airplane cabin interior. It appears that, provided sufficient care is taken in the measurements, accurate quantitative information can be obtained with this technique on the dominant paths of acoustic energy transmission. This information can be used to make design changes to the fuselage wall to reduce interior cabin noise.

**84-1930**

**Structureborne Contribution to Interior Noise of Propeller Aircraft**

V.L. Metcalf and W.H. Mayes

Army Structures Lab., Hampton, VA, SAE Paper No. 830735

Key Words: Aircraft noise, Interior noise, Structure borne noise

Measurements obtained for ground tests on a Twin Otter aircraft show that structureborne noise is a major contributor to the interior noise level. The structureborne source was the propeller blade wake and tip vortex interaction with the wing and contributes at the blade passage frequency and its harmonics.

**84-1931**

**The Prediction of Interior Noise of Propeller-Driven Aircraft: A Review**

J.F. Wilby

Bolt Beranek and Newman, Inc., Canoga Park, CA, SAE Paper No. 830737

Key Words: Aircraft noise, Interior noise, Noise prediction, Reviews

Recently developed analytical models for the airborne transmission of propeller noise into airplane cabins are reviewed. Different aspects considered are the representations for the exterior pressure field, fuselage structure and cabin volume. The analytical models require that the excitation be described in terms of amplitude and phase so that the structural response can be calculated.

**84-1932**

**Fokker's Activities in Cabin Noise Control for Propeller Aircraft**

E.H. Waterman, D. Kaptein, and S.L. Sarin

Fokker B.V., Schiphol, The Netherlands, SAE Paper No. 830736

Key Words: Aircraft noise, Noise reduction, Dynamic absorbers, Damping

This paper deals with the noise control measures which have been applied successfully on the propeller-driven Fokker F27 Friendship aircraft. The measures described include the application of dynamic absorbers, double walls, damping treatments and synchrophasing. Provisions for suppressing rattles are also discussed.

**84-1933**

**An Improved Method for Predicting Lateral-Directional Dynamic Stability Characteristics**

H.S. Bruner

Beech Aircraft Corp., SAE Paper No. 830711

Key Words: Aircraft, Dynamic stability, Prediction techniques

Current methods of predicting lateral-directional dynamic stability using closed form small perturbation equations are often inaccurate. Flight test data usually shows Dutch-roll characteristics, in particular, to be poorer than estimates. Two assumptions are inherent in these current methods that are inappropriate to general aviation-type aircraft: first, that the control surfaces are fixed and, secondly, that the rate-of-change in sideslip (beta dot) stability derivatives are insignificant. These assumptions are discarded in this new method, and the system of equations describing the aircraft motion are expanded.

**84-1934**

**Survey of Serious Aircraft Accidents Involving Fatigue Fracture. Volume 1. Fixed-Wing Aircraft**

G.S. Campbell and R.T.C. Lahey

National Aeronautical Establishment, Ottawa, Ontario, Canada, Rept. No. NAE-AN-7, NRC-21276, 153 pp (Apr 1983)

AD-A137 254

Key Words: Aircraft, Fatigue life

A world-wide survey was done of serious aircraft accidents involving fatigue fracture. A total of 1466 fixed-wing accidents since 1927 were identified as having fatigue fracture as a related cause, and these accidents resulted in 1861 fatalities. The accidents cover civil and, to a limited extent, military aircraft. Accidents are listed by failure type, as well as by aircraft type. Engine/transmission failure and landing-gear failure were the most common cause of recent fixed-wing accidents, and currently there is an average of about 69 fixed-wing fatigue accidents per year.

**84-1935**

**Survey of Serious Aircraft Accidents Involving Fatigue Fracture. Volume 2. Rotary-Wing Aircraft**

G.S. Campbell and R.T.C. Lahey

National Aeronautical Establishment, Ottawa, Ontario, Canada, Rept. No. NAE-AN-8, NRC-21277, 98 pp (Apr 1983)

AD-A137 255

Key Words: Helicopters, Fatigue life

Volume 2 of a world-wide survey of serious aircraft accidents involving fatigue fracture deals with rotary-wing aircraft. A total of 419 rotary-wing accidents since 1937 were identified as having fatigue fracture as a related cause, and these accidents resulted in 379 fatalities. The accidents cover civil and, to a limited extent, military aircraft. Accidents are listed by failure type, as well as by aircraft type. Engine/transmission failure and tail-rotor failure were the most common cause of rotary-wing accidents, and currently there is an average of about 31 rotary-wing fatigue accidents per year.

**84-1936**

**Crash Impact Characteristics of Helicopter Composite Structures**

J.D. Cronkhite

Bell Helicopter Textron, Inc., Fort Worth, TX, SAE Paper No. 830749

Key Words: Crash research (aircraft), Helicopters, Crashworthiness, Experimental data, Computer programs

The results of a research program to investigate the crash impact behavior of helicopter composite structures designed to meet the U.S. Army's crashworthiness requirements specified in MIL-STD-1290 are described. The program included design, fabrication, and crash testing of two full-scale composite helicopter cabin sections.

**84-1937**

**Crashworthiness Analysis of Aircraft Seats Using Program SOM-LA**

D.H. Laananen, L.M. Neri, and C.E. Nuckolls

Simula, Inc., SAE Paper No. 830747

Key Words: Crash research (aircraft), Aircraft seats, Safety restraint systems, Crashworthiness

Program SOM-LA (seat/occupant model - light aircraft) has been developed for use in evaluating the crashworthiness of aircraft seats and restraint systems. It combines a three-dimensional dynamic model of the human body with a finite element model of the seat structure. The seat analysis has the capability to model large displacements, nonlinear material behavior, local buckling, and various internal releases for beam elements. The final phase of validation included simulation of dynamic tests of production general aviation seats. Model predictions are compared with test data for one of these seats.

**84-1938**

**Aircraft Crash Safety Research in Australia**

S. Sarrailhe

Aeronautical Res. Labs., Melbourne, Australia, SAE Paper No. 830745

Key Words: Crash research (aircraft), Energy absorption

A limited program of crash safety research has been conducted which included investigations into the performance of conventional and energy absorbing restrain systems, the strength of cabins and the response of light aircraft seats to vertical acceleration. Results are presented and some improved experimental techniques are suggested.

**84-1939**

**Impulse Analysis of Airplane Crash Data with Consideration Given to Human Tolerance**

H.D. Carden

NASA Langley Res. Ctr., Hampton, VA, SAE Paper No. 830748

Key Words: Crash research (aircraft), Human response

An impulse-momentum analysis was conducted of crash deceleration pulse data from a crash dynamics program on general aviation airplanes and transport crash data available in the literature. The purpose of the analysis was to correlate crash data with flight parameters at impact.

## MISSILES AND SPACECRAFT

**84-1940**

**Study on Damping Representation Related to Spacecraft Structural Design**

E. Hilbrandt

Dornier-Werke GmbH, Friedrichshafen, Fed. Rep. Germany, Rept. No. EMSB-18/83, ESA-CR(P)-1770, 210 pp (Feb 1983)

N84-15182

Key Words: Viscous damping, Damping, Spacecraft

Damping representation models for spacecraft dynamic response analysis, and system damping prediction methods were analyzed. Results show that the only suitable damping model is the viscous damping model. Differences between random and harmonic test methods are treated and system identification with random response data is discussed.

# BIOLOGICAL SYSTEMS

## HUMAN

(Also see Nos. 1918, 1919)

**84-1941**

**Critique of Subjective Responses of Chinese to Aircraft Noise**

A.L. Brown

Environmental Protection Agency, Empire Centre, Tsim Sha Tsiu, Kowloon, Hong Kong, Appl. Acoust., 17 (3), pp 223-232 (1984) 2 figs, 2 tables, 9 refs

Key Words: Aircraft noise, Human response

A reported difference in response to aircraft noise between the community living around Hong Kong International Airport and that living around Heathrow Airport in the UK has been ascribed to a different sensitivity of Chinese in Hong Kong to aircraft noise. This paper questions whether any such difference exists and suggests that the result is more likely a function of the techniques of survey and analysis adopted in the Hong Kong study.

**84-1942**

**Prediction of In-Cab Noise Exposure of Drivers**

Z.F. Reif and T.N. Moore

Univ. of Windsor, Windsor, Ontario, Canada, SAE Paper No. 831028

Key Words: Trucks, Interior noise, Human response

The noise levels within truck cabs and the noise exposure of drivers were measured during commercial payload runs with an instrument of special design. Sound levels were continuously recorded within both ears of the driver and at the center of the cab station. A relatively simple formula was developed for the prediction of noise exposure.

**84-1943**

**Mining Machinery Noise Control Guidelines, 1983: Bureau of Mines Handbook**

R.C. Bartholomae and R.P. Parker

Pittsburgh Res. Ctr., Bureau of Mines, Pittsburgh, PA, Rept. No. BUMINES-HB-2-83, 90 pp (Dec 1983)

PB84-152958

Key Words: Machinery noise, Mines (excavations), Human response, *Manuals and handbooks*

A number of noise control programs aimed at establishing a technology base that can be used by industry to effect solutions to noise problems have been undertaken. Many of these hardware-oriented programs have provided the development and demonstration of retrofit noise control treatments for mining machinery. The purpose of this handbook is to synthesize evolving and available noise control information and disseminate it within the mining industry.

**84-1944**

**Methods for Predicting Passenger Vibration Discomfort**

K.C. Parsons and M.J. Griffin

Southampton Univ., SAE Paper No. 831029

Key Words: Ground vehicles, Vibration prediction, Human response

Measurements of vehicle vibration and passenger discomfort have been used to evaluate alternative methods of predicting passenger vibration discomfort. Twelve vibration inputs to the body were considered: three translational and three rotational axes on the seat, three translational axes at the back and three translational axes at the feet. Equivalent comfort contours were obtained by laboratory experimentation for all twelve inputs for eight male subjects. The responses of these subjects to the ride in six different cars on twelve different roads were then correlated with nine alternative methods of averaging the twelve vibration inputs.

**84-1945**

**Occupant Injury Patterns in Side Impacts -- A Coordinated Industry/Government Accident Data Analysis**

S.C. Partyka and S.E. Rezabek

U.S. Dept. of Transportation, National Highway Traffic Safety Admn., SAE Paper No. 830459

Key Words: Collision research (automotive), Human response

The accident data analysis task group of a coordinated government/industry project to develop and compare full-scale with subsystem side impact test procedures investigated four areas of side impact injuries. The task group ranked crash configuration modes, established injury categories based on predominant body region injured and vehicle interior component contacted, investigated the relationship between these first and second impact variables, and discussed the role of structural integrity to occupant injury.

**84-1946**

**What is a Realistic Lateral Impact Test?**

W. Reidelbach and F. Zeidler

Daimler-Benz AG, Stuttgart, W. Germany, SAE Paper No. 830460

Key Words: Collision research (automotive), Testing techniques, Human response

From accident investigation files, 222 side collision reports were selected and ranked according to injury severity of car occupants. Those collisions which caused serious to fatal injuries were then analyzed regarding direction of impact, mass and rigidity of impacting object, degree of injury risk attributed to the occupant seating position, and distribution of injuries over the body areas (head, thorax, pelvis). The findings on direction and rigidity of impact support the proposal to continue using the conventional rigid moving barrier but the injury distribution data underline the need to accelerate the development of improved anthropomorphic dummies suitable to simulate human kinematic characteristics.

**84-1947**

**Conditions Required to Avoid Being Killed in Cars in Side Impact**

J.Y. Foret-Bruno, F. Hartemann, C. Tarriere, C. Got, and A. Patel

Laboratoire de Physiologie et de Biomecanique Peugeot S.A./Renault, France, SAE Paper No. 830461

Key Words: *Collision research (automotive), Human response*

*The conditions in which side impacts have led to the death of 369 car occupants are studied.*

**84-1948**

**An Algorithm for Determining the Head Injury Criterion (HIC) from Records of Head Acceleration**

B.E. Rodden, T.J. Bowden, and J.K. Reichert

Defence and Civil Inst. of Environmental Medicine, Downsview, Ontario, SAE Paper No. 830469

Key Words: Collision research (automotive), Head (anatomy)

An algorithm for calculating the head injury criterion (HIC) from a digital record of the resultant head acceleration of a dummy used in impact testing is described. A result from Chou and Nyquist is used to establish a procedure for searching the range of time intervals within the acceleration pulse which should guarantee finding the true HIC. A second result is used to make the search far more efficient for most head acceleration records. The algorithm is implemented in a simple way which does not require curve-fittng or interpolation between the data points.

**84-1949**

**Learning from Child Protection Devices and Concepts from Outside of the United States**

C.C. Clark

National Highway Traffic Safety Admn., SAE Paper No. 831666 (P-135)

Key Words: Collision research (automotive), Human response, Safety restraint systems

Successful devices for child crash protection from outside the United States are tested. Test results and possible problems are presented for a transverse infant bed, a toddler backward facing seat, an older child booster seat with back and head supports, and the Australian "Sit-Safe" design, an inexpensive belt to go between the shoulder strap and the lap belt to insure that the shoulder belt does not touch the child's neck.

**84-1950**

**Pedestrian Hip Impact Simulator Development and Hood Edge Location Consideration on Injury Severity**

H.B. Pritz and J.M. Pereira

National Highway Traffic Safety Admn., SAE Paper No. 831627 (P-134)

Key Words: Collision research (automotive), Human response

This paper describes an upper leg impact simulator that is representative of the dynamics of impacts between the pedestrian hip or upper leg and the vehicle hood edge. Cadaver tests have been analyzed to obtain the actual velocity of the upper leg as it strikes the hood edge. It is found that the impact velocity of the hip or upper leg onto the hood edge is approximately one third of the vehicle velocity for a conventional vehicle front.

**84-1951**

**Study of "Knee-Thigh-Hip" Protection Criterion**

Y.C. Leung, B. Hue, A. Fayon, C. Tarriere, H. Hamon, C. Got, A. Patel, and J. Hureau

Laboratory of Physiology and Biomechanics, Peugeot-Renault Assn., France, SAE Paper No. 831629 (P-134)

Key Words: Collision research (automotive), Cadavers

A series of fresh human cadaver and Part 572 dummy tests was performed under different conditions which were comparable to those of real-world accidents. A European car model mounted on a sled was used; a pair of knee-targets was fixed directly to the car body in front of the passenger knees. Since the knee-thigh-hip tolerance is related to the shape and duration of the impact pulse, these interactions were the subject of study.

**84-1952**

**Side Impact -- A Comparison Between HSRI, APROD and HYBRID II Dummies and Cadavers**

G. Klaus and D. Kallieris

Volkswagenwerk AG, Wolfsburg, SAE Paper No. 831630 (P-134)

Key Words: Collision research (automotive), Experimental data, Anthropomorphic dummies, Cadavers

The paper presents and describes results of the FAT research-project Phase I "Kinematics and Loadings during Side Impacts: Comparison between Dummies and Cadavers." It reports on 30 side impacts at 50 km/h under 90° impact angle conducted with three different dummies and cadavers. On the basis of the test results dummy modifications will be proposed.

**84-1953**

**Lateral Protection of Passenger Cars -- Comparison Tests by Means of Different Barrier Configurations**

W. Sievert and E. Pullwitt

Traffic Safety and Accident Res. Dept., Fed. Highway Res. Inst. (BASt), Cologne, SAE Paper No. 831631 (P-134)

Key Words: Collision research (automotive), Experimental data, Anthropomorphic dummies

The results obtained from a series of tests are described, comparing the effects (deformations and dummy load values) caused by lateral collisions at right angles on a subcompact car, impacted by a car of the same type, by an intermediate car and also by barriers with a rigid front and a deformable front.

**84-1954**

**Evaluation of Side Impact Protection in Barrier to Car Tests**

D. Cesari, R. Zac, and A. Johnson

ONSER-Laboratoire des chocs et de biomecanique, Bron, France, SAE Paper No. 831632 (P-134)

Key Words: Collision research (automotive), Anthropomorphic dummies, Cadavers

Eight barrier to car side impact tests were conducted with dummies and with cadavers. Two types of car were used: an unmodified (baseline) Rabbit, and a modified (for side impact protection) Rabbit. The modifications concern the reinforcement of the side structures and the use of an internal padding for protection of pelvis and thorax.

**84-1955**

**Human Response to and Injury from Lateral Impact**

J.H. Marcus, R.M. Morgan, R.H. Eppinger, D. Kallieris, and G. Schmidt

National Highway Traffic Safety Admn., Washington, DC, SAE Paper No. 831634 (P-134)

Key Words: Collision research (automotive), Human response

*Lateral impacts have been shown to produce a large portion* of both serious and fatal injuries within the total automotive crash problem. In an effort to understand the mechanisms of these injuries, an experimental program using human surrogates (cadavers) was initiated. Initial impact velocity and compliance of the lateral impacting surface were the primary test features that were controlled, while age of the test specimen was varied to assess its influence on the injury outcome. Instrumentation consisted of 24 accelerometer channels on the subjects along with contact forces measured on the wall both at the thoracic and pelvic level.

**84-1956**

**Crash Victim Simulation -- A First Step in Child Auto Safety**

R.L. Stalnaker

Ohio State Univ., Columbus, OH, SAE Paper No. 831661 (P-135)

Key Words: Collision research (automotive), Human response, Computer programs

The role of CVS computer programs in child automotive safety is discussed. Examples of how the MADYMO CVS program has been used to determine feasibility, design, optimization, patent right definition, and improved performance of child restraint systems are presented.

**84-1957**

**An Analytical Model of Children in a Panic Braking Environment with Experimental Validation**

P.H. Cheng and D.A. Guenther

Ohio State Univ., Columbus, OH, SAE Paper No. 831662 (P-135)

Key Words: Collision research (automotive), Braking effects, Human response

A linear acceleration sled device developed to study child responses to panic braking environments is described. A sled with a vehicle seat and soft simulated dash is accelerated by a drop weight in a similar fashion to actual vehicle decelerations when panic braking. A simple, two degree of freedom analytical model of the experimental device was developed to predict the dynamic performance of the sled and examine the sensitivity of various parameters in producing acceleration time histories of actual braking vehicles.

**84-1958**

**From Three-Years-Old to Adult Size -- How to Ensure Child Protection in Automobile Accidents**

C. Tarriere, C. Thomas, F. Brun-Cassan, C. Got, and A. Patel

Laboratoire de Physiologie et de Biomecanique, Peugeot S.A./Renault, SAE Paper No. 831664 (P-135)

Key Words: Collision research (automotive), Human response

Recently, new restraint devices, called cushions, were developed for children over 3 which can be used almost up to small adult sizes. They enable some improvements in the location of the adult belt on the child's body; thus, improving safety. This cushion was tested with 3-year and 6-year child dummies and proved to be very efficient from a safety standpoint as well as being comfortable.

**84-1959**

**Experimental Study of a Compliant Bumper System**

O. Bunketorp, B. Romanus, T. Hansson, B. Aldman, L. Thorngren, and R.H. Eppinger

Dept. of Orthopaedic Surgery, Univ. of Goteborg, SAE Paper No. 831623 (P-134)

Key Words: Collision research (automotive), Bumpers, Human response

An ordinary rigid bumper system and a compliant bumper system for pedestrian protection were compared in an experimental study of leg injuries in car-pedestrian accidents. A lower bumper level than today's standard and a compliant bumper type is recommended in combination to reduce the risk of serious leg injuries in car-pedestrian accidents.

**84-1960**

**Observed Misuse of Child Restraints**

A. Shelness and J. Jewett

Physicians for Automotive Safety, SAE Paper No. 831665 (P-135)

Key Words: Collision research (automotive), Crashworthiness, Safety restraint systems, Human response

Correct use of child restraining devices (CRDs) is essential; misuse reduces or could even defeat the protective potential. To establish the magnitude of one part of the misuse problem, observers examined installation of CRDs in the forward-facing toddler mode for errors in seat belt routing and top tether installation. The consequences of misuse are touched upon, possible reasons for misuse are discussed, and remedies are suggested.

**84-1961**

**An Analysis of the Vehicle-Occupant Impact Dynamics and Its Application**

M. Huang

Ford Motor Co., SAE Paper No. 830977

Key Words: Collision research (automotive), Human response

The vehicle-occupant impact dynamics during a crash are studied using a simple mathematical model. The model yields explicit analytical relationships between occupant responses and physical parameters of the vehicle structure and occupant restraint system. These parametric relationships, verified by experimental crash tests of the total system, are useful in describing the physical concepts of the impact event, and predicting occupant dynamic behavior during a vehicle crash.

**84-1962**

**Cervical Spine Injury Mechanisms**

G.S. Nusholtz, D.E. Huelke, P. Lux, N.M. Alem, and F. Montalvo

Univ. of Michigan, Ann Arbor, MI, SAE Paper No. 831616 (P-134)

Key Words: Collision research (automotive), Cadavers, Human response

A test series using eight unembalmed cadavers was conducted to investigate factors affecting the creation of cervical spine damage from impact to the crown of the head. The crown impact was accomplished by a free-fall drop of the test subject onto a load plate. Load and acceleration data are presented as a function of time and as a function of frequency in the form of mechanical impedance.

**84-1963**

**The Structure of European Research into the Biomechanics of Impacts**

B. Aldman, H. Mellander, and M. Mackay

Chalmers Technical Univ., Goteborg, Sweden, SAE Paper No. 831610 (P-134)

Key Words: Collision research (automotive), Human response

Some of the trends in biomechanical research in Europe are reviewed. Current terminology is discussed and a set of definitions is proposed for the common descriptors of injury, injury severity and performance criteria based on the responses observed in the living human body, in cadavers and in other surrogates.

**84-1964**

**Biomechanical Accident Investigation Methodology Using Analytical Techniques**

D.H. Robbins, J.W. Melvin, D.F. Huelke, and H.W. Sherman

Univ. of Michigan, Ann Arbor, MI, SAE Paper No. 831609 (P-134)

Key Words: Collision research (automotive), Human response, Computer-aided techniques

The purpose of this paper is to describe a combination of state-of-the-art detailed accident investigation procedures, computerized vehicle crash and occupant modeling, and biomechanical analysis of human injury causation into a method for obtaining enhanced biomechanical data from car crashes.

**84-1965**

**The Influence of Impact Energy and Direction on Thoracic Response**

G.S. Nusholtz, J.W. Melvin, and P. Lux

Transportation Res. Inst., Univ. of Michigan, Ann Arbor, MI, SAE Paper No. 831606 (P-134)

Key Words: Collision research (automotive), Cadavers

A test series using unembalmed cadavers was conducted to investigate thoracic response differences in lateral impacts between high energy (rib fractures produced) and low energy (no rib fractures produced) testing and also the response to low energy impacts for different impact directions (frontal, 45°, and lateral). Five of the test subjects were instrumented with a *nine*-accelerometer package and an eighteen-accelerometer array to measure thoracic response. Seven of the test *subjects were instrumented* with a triaxial accelerometer on the head and a six-accelerometer array to measure thoracic response.

### 84-1966

**Injury Mechanisms to Occupants Restrained by Three-Point Seat Belts in Side Impacts**

D.J. Dalmotas

Vehicle Systems, Road and Motor Vehicle Traffic Safety, Transport Canada, SAE Paper No. 830462

Key Words: Automobile seat belts, Human response, Collision research (automotive)

The current limits of protection afforded vehicle occupants restrained by conventional three-point seat-belt assemblies in side impacts are examined. The sample under consideration *comprises* 98 *restrained* passenger vehicle occupants involved either in a near side or a far side impact, each of whom sustained at least one injury at the AIS 2 or greater severity level (1976 AIS Dictionary). A detailed description of the pattern of injury to this subset of occupants and the damage sustained by the vehicle is presented.

### 84-1967

**Comparison of Current Anthropomorphic Test Devices in a Three-Point Belt Restraint System**

R.A. Saul, L.K. Sullivan, J.H. Marcus, and R.M. Morgan

Vehicle Res. and Test Ctr., East Liberty, OH, SAE Paper No. 831636 (P-134)

Key Words: Safety restraint systems, Anthropomorphic dummies

Frontal sled tests of the Part 572, APR, and Hybrid *III* dummies were conducted in a three-point restraint system at 50 km/hr velocity change. The tests were conducted to evaluate the dummy responses in a tightly controlled systems environment, and to compare the dummy responses to previously established cadaver responses from the same environment.

### 84-1968

**Injury Potential with Misused Child Restraining Systems**

K. Weber and J.W. Melvin

Transportation Res. Inst., Univ. of Michigan, Ann Arbor, MI, SAE Paper No. 831604 (P-134)

Key Words: Safety restraint systems, Human response

Current restraint designs, misused in common ways, were studied using a variety of dummies under FMVSS-213 impact test conditions. Configurations addressed in this series include improperly installed child restraints, misused infant restraints, multiple children in too few belts, and a misused booster. Kinematic data from high-speed films are presented as well as appropriate load and acceleration data.

### 84-1969

**An Experimental Study of the Effects of Child Restraint Improper Installation and Crash Protection for Larger Size Children**

B.J. Kelleher, M.J. Walsh, D.M. Dance, and W.T. Gardner

Calspan Advanced Tech. Ctr., Buffalo, NY, SAE Paper No. 831602 (P-134)

Key Words: Safety restraint systems, Human response

Results of child restraint system performance during dynamic testing of proper and improper installation configurations are presented and discussed. Over 75 frontal and oblique sled tests were performed using either an SA1001 six-month old infant size, an SA103C three-year-old toddler size or a VIP-6C six-year-old size dummy. Also included are results of sled tests of restraint systems (both commercially available and homemade/improvised) which are intended to protect larger size children. Data presented include head and knee excursions compared with available space in selected vehicles as well as head and chest accelerations and HIC values where applicable.

### 84-1970

**Pedestrian Impact Simulation -- A Preliminary Study**

M.K. Verma and B.S. Repa

General Motors Res. Labs., Warren, MI, SAE Paper No. 831601 (P-134)

Key Words: Collision research (automotive), Human response

Results obtained from analytical three-dimensional motion *simulations of child and adult pedestrians impacted* by an automobile are described. The baseline geometric and stiffness parameters used in this simulation correspond to a typical mid-size vehicle, the latter being measured by a dynamic impactor developed for this study. The effects of variation of several of the vehicle's front-end design parameters on the impact severities of a 50th-percentile male adult and a 6-year-old child pedestrian are studied using experimental design techniques. Both the main effects and the first-order interactions among the parameters are investigated.

## ANIMAL

(See No. 1939)

# MECHANICAL COMPONENTS

## ABSORBERS AND ISOLATORS

(Also see Nos. 1918, 1919, 2109)

**84-1971**

**Some Properties of an Active Electropneumatic Vibration Control System**

M. Gajarský

Inst. of Materials and Machine Mechanics of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnicky Casopis, 35 (1-2), pp 51-65 (1984) 7 figs, 18 refs (In Slovak)

Key Words: Active vibration control

An active vibration control system with air-buffer being electronically controlled is examined. The nonlinear dynamical model is described and its properties discussed. Results of analog computer simulation are presented.

**84-1972**

**Engine Mount for Integral Body Vehicle**

J.A. Cogswell and D.E. Malen

General Motors Corp., SAE Paper No. 830258

Key Words: Vibration isolation, Engine mounts, Noise reduction

A typical problem in integral body vehicles is the isolation of high frequency vibration and noise. A method of attacking this problem is presented for isolation of engine noise. A mount concept which acts as a mechanical low pass filter was analyzed, designed and tested. Results in reducing engine noise in the vehicle show it to be an effective method.

**84-1973**

**Simulation of Engine Idle Shake Vibration**

C.J. Radcliffe, M.N. Picklemann, C.E. Spiekermann, and D.S. Hine

College of Engrg., Michigan State Univ., East Lansing, MI, SAE Paper No. 830259

Key Words: Vibration isolation, Engine vibration, Simulation

To assist in the development of engine vibration isolation techniques for new transverse front wheel drive vehicles, simulations of engine and vehicle structural response were developed. A simulation of engine vibration response to engine imbalance forces and firing pulses is presented which provided mount forces as input to a vehicle structure simulation. Current design techniques using properties of engine rigid body motion are discussed.

**84-1974**

**Experimental Research of Dynamic Properties of the Operator Seat of an Earth Moving Vehicle with an Active Vibration Control System**

I. Ballo, N. Szuttor, and J. Stein

Inst. of Materials and Machine Mechanics of Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 7-17 (1984) 5 figs, 1 table, 19 refs (In Slovak)

Key Words: Earth handling equipment, Seats, Active vibration control

Practical experience and theoretical considerations have shown, that for operator seat in an earth moving vehicle passive vibration control means based on a system of springs and dampers are insufficient. Therefore various active vibration control means are under development, based on a hydraulic servocylinder controlled by the accelerometer signal derived from cabin floor vibration. A dummy active vibration control system is described along with test stand and measuring complex which were used for evaluation of dummy system properties.

## 84-1975
**Shock Isolated Accelerometer**

M. Groethe and E. Day

S-Cubed, La Jolla, CA, Rept. No. SSS-IR-83-6141, 18 pp (June 1983) (Transducer Workshop (12th) held at Melbourne, FL, June 7-9, 1983, pp 516-533) AD-P002 692

Key Words: Shock isolators, Accelerometers

A novel concept for isolating an accelerometer from large, potentially damaging, transient accelerations is presented. It consists of a piston, bore, and a present frictional force between the two. The accelerometer is mounted on the piston. The piston will displace relative to the bore when the input force to the bore is equal to or greater than the frictional force. By knowing the total piston mass and frictional force between it and the bore, an upper limit to the transmitted acceleration is defined.

## 84-1976
**Ground and Flight Tests of a Passive Rotor Isolation System for Helicopter Vibration Reduction**

D. Braun

Messerschmitt-Bölkow-Blohm GmbH, 8000 München 80, Fed. Rep. Germany, Vertica, 8 (1), pp 1-14 (1984) 18 figs, 8 refs

Key Words: Isolators, Rotor-induced vibration, Helicopter vibration, Vibration control

One method of reduction of the rotor induced cabin vibrations consists of separating the helicopter airframe dynamically from the rotor-transmission unit by use of convenient isolator elements. This paper deals with the development of a passive nodal rotor isolation system for the BK 117 helicopter. It consists essentially of five local uniaxial force isolators which operate according to the well known antiresonance principle and which are tuned to the 4/rev main excitation frequency.

## 84-1977
**Design of the Low Vibration Turboprop Powerplant Suspension System for the DASH 7 Aircraft**

G.O. Hrycko

The de Havilland Aircraft of Canada, Limited, SAE Paper No. 830755

Key Words: Engine mounts, Aircraft vibration, Vibration control

Described in this paper is the two-plane engine mounting scheme used successfully in de Havilland's DASH 7 commuter aircraft. The suspension system meets the design objectives of low transmissibility, adequate whirl flutter margins and minimized landing loads.

## 84-1978
**State Space Method for Optimal Design of Shock Absorbers with Floating Boundaries**

K. Kasraie

Ph.D. Thesis, Pennsylvania State Univ., 208 pp (1983)
DA8327511

Key Words: Shock absorbers, Optimum design, State space approach, Viscous damping

The state space method for optimal design of vibration isolators is used and advanced to include a more general class of problems encountered in the optimal design of shock absorbers. In contrast to the state space optimization, in which forcing functions, cost function and performance constraints are explicitly independent of the state variable vector at some floating boundaries, in the new formulation of the problem, forcing functions, cost function and performance constraints can be a function of the state variable vector at some moving boundaries. An example of this type of problem is the design of the elastic-plastic shock absorbers for optimum performance during loading and unloading.

## 84-1979
**The Role of Steering Wheel Structure in the Performance of Energy Absorbing Steering Systems**

J.D. Horsch and C.C. Culver

Biomedical Science Dept., GM Res. Labs., SAE Paper No. 831607 (P-134)

Key Words: Steering gear, Automobile steering columns, Energy absorption

This study identifies important parameters that influence the basic response mechanics of a compressible column steering assembly. Energy can be absorbed either by column compression and/or steering wheel deformation, depending on relative deformation force. Neither column compressive force nor steering wheel deformation force are uniquely defined but depend on several parameters.

## 84-1980

**Suspension Design for Optimum Road-Holding**

A.G. Thompson

Univ. of Adelaide, Adelaide, South Australia, SAE Paper No. 830663

Key Words: Suspension systems (vehicles)

Formulas are developed for the optimum spring and damper rates in conventional car suspensions. The formulas are based on the minimization of the mean-squared tire forces on random roads. The suspension spring rates are optimally tuned in relation to the tire radial rates and the optimal spring and damper rates are independent of speed. Frequency locus methods are employed in the theory which is based on a linear half-car model.

## 84-1981

**Progress in British Tracked Vehicle Suspension Systems**

B. Maclaurin

Military Vehicles & Engrg. Establishment, UK, SAE Paper No. 830442

Key Words: Suspension systems (vehicles), Tracked vehicles

The higher power/weight ratios of modern tracked armored vehicles has increased potential cross-country speed and placed greater demands on vehicle suspension systems. This has led to advances in component hardware and techniques for predicting and measuring suspension performance. The paper describes the use of computer modeling for comparing the effects of different suspension characteristics and the use of concrete profiles including a random profile course for measuring performance and validating models. Two modern tracked vehicle suspension systems are described.

## 84-1982

**The Development of the Suspension System Used on the Nissan Stanza -- A New Front-Wheel-Drive Compact Car**

H. Kan, T. Kawaura, and M. Iki

Nissan Motor Co., Ltd., SAE Paper No. 830980

Key Words: Suspension systems (vehicles)

The suspension system of the Nissan Stanza was specifically designed for use on a front-wheel-drive car. It was developed with the idea that the new suspension should be compact and light, and afford a comfortable ride as well as good stability and controllability. Furthermore, it should have excellent noise and vibration characteristics. To achieve these objectives a strut suspension was adapted for both the front and rear, and careful consideration was given to the fundamental specifications.

## 84-1983

**Motorcycle Suspension Design -- State-of-the-Art Survey, 1983**

J.S. McKibben

McKibben Engrg. Corp., SAE Paper No. 830152

Key Words: Suspension systems (vehicles), Motorcycles, Design techniques, Reviews

Evolutionary changes have produced significant improvements in motorcycle ride, handling, stability and control. These changes include improvements in chassis geometry, wheel travel, damping, user adjustability and structural stiffness. Within the last decade, both highway and offroad motorcycles have achieved substantially higher levels of chassis performance. Using current model machines, it is possible to clearly identify trends in chassis development, and to illustrate the very high level of technical sophistication of modern motorcycles.

# TIRES AND WHEELS

## 84-1984

**Acquisition of Transient Tire Force and Moment Data for Dynamic Vehicle Handling Simulations**

A. Sitchin

Ford Motor Co., SAE Paper No. 831790

Key Words: Tire characteristics, Tires, Transient excitation, Testing techniques, Experimental data, Force coefficients, Moment coefficients

The issues encountered in using conventionally acquired tire test data for dynamic total vehicle handling simulations and the need for improved methodology are described. The new test procedure used to acquire all three forces and three moments in a transient mode for a matrix of loads, slip and camber angles is also described. A study of the test data supports the premises that the overturning moment, Mx, should not be neglected in dynamic simulations, and that the effects of camber should not be treated as only an independent, linearly additive, camber thrust.

**84-1985**
**Research on Vibration of Motor Vehicle Front Wheels**
Guan Di-Hua
Tsing-Hua Univ., China, SAE Paper No. 830893 (P-139)

Key Words: Wheels, Motor vehicles, Vibration analysis

The common feature of forced and self-excited vibrations encountered in motor vehicle front wheels lies in the fact that a certain amount of energy is fed back via tire-road interaction from the engine to front axle steering system, which may result in the presence of negative damping as in self-excited vibration. This paper presents two mathematical models for vibration analysis; namely, an eighth order mathematical model of the front-axle steering system and a composite mathematical model comprising both front-axle steering system and the whole suspended structure with its own modal parameters.

## BLADES

**84-1986**
**The Coupled Response of Turbomachinery Blading to Aerodynamic Excitations**
D. Hoyniak and S. Fleeter
Purdue Univ., West Lafayette, IN, J. Aircraft, 21 (4), pp 278-286 (Apr 1984) 18 figs, 7 refs

Key Words: Blades, Turbomachinery blades, Aerodynamic loads, Energy balance technique, Coupled response

An energy balance technique is developed which predicts the coupled bending-torsion mode aerodynamic forced response of an airfoil. The effects of the various aerodynamic parameters are then considered utilizing a subsonic compressible flow/flat plate cascade gust analysis. The increased coupling between the torsion and translation modes as the natural frequencies approach one another is shown.

**84-1987**
**Vibrations of Bladed-Disk Assemblies – A Selected Survey**
A.V. Srinivasan
United Technologies Res. Ctr., East Hartford, CT, Intl. Fed. of Theory of Machines and Mechanisms, 6th Congress, Tech. Committee on Rotordynamics Session Proc., Indian Inst. of Tech., New Delhi, India, Dec 19, 1983, pp 60-65, 43 refs

Key Words: Jet engines, Blades, Vibration analysis, Reviews

The progress made in the decade 1973-1983 in the area of vibration of jet engine blades is surveyed. The purpose of the survey is to provide a general review of recent progress and the limited number of references cited can be used to reach the many other important publications in this area. Both structural and aerodynamic aspects of blade vibration are discussed. The areas of future analytical and experimental research needed to continue to influence the design of these components are outlined.

**84-1988**
**Single Blade Dynamics**
J.S. Rao
Indian Inst. of Tech., New Delhi, India, Intl. Fed. of Theory of Machines and Mechanisms, 6th Congress, Tech. Committee on Rotordynamics Session Proc., Indian Inst. of Tech., New Delhi, India, Dec. 19, 1983, pp 41-59, 1 fig, 162 refs

Key Words: Blades, Turbomachinery blades, Natural frequencies, Mode shapes, Damping

This paper presents some of the important contributions made in the dynamic analysis of single blades used in turbomachines and discusses the state-of-the-art of the subject, deficiencies in specific areas and possible future course of action towards more efficient design methods. The areas considered include nonsteady forces in a turbomachine stage, natural frequencies and mode shapes, damping, forced vibrations and the resulting dynamic stresses induced in a blade.

## BEARINGS
(Also see No. 2098)

**84-1989**
**Sound Solution to a Shaky Situation**
A. Hitchcox, Assoc. Editor
Power Transm. Des., 26 (3), pp 48-50 (Mar 1984) 5 figs

Key Words: Bearings

Bearings for heavy off-highway equipment which withstand heavy vibration, misalignment and high temperatures, are described.

### 84-1990

**Dynamic Behaviour of an Elastic Connecting-Rod Bearing -- Theoretical Study**

B. Fantino, M. Godet, and J. Frene

Laboratoire de Mecanique des Contacts, INSA Lyon, France, SAE Paper No. 830307 (SP-539)

Key Words: Bearings, Journal bearings

The dynamic behavior of an elastic connecting-rod bearing is studied using an iterative method. Short bearing approximation for Reynolds' equation and plane elasticity relations for the bearing housing are used for this study.

### 84-1991

**The Influence of Misalignment on Self-Lubricated Bearings**

J.H. Cooper

Garlock Bearings, Inc., SAE Paper No. 831370

Key Words: Bearings, Alignment, Off-highway vehicles

In all structures there are several reasons why misalignment can occur at a bearing. This is especially true with large structures such as off-highway equipment of all types, agricultural tractors and implements and roadway vehicles. Misalignments can be attributed to distortion in welded units. Efforts to line bore long distances and simply the accumulation of tolerances on several parts also cause alignment problems. Even with the designer's diligent efforts to reduce tolerancing and manufacturing inaccuracies, the bearing surface will still be subjected to structural misalignment simply due to load application.

### 84-1992

**Experimental Study of Journal Bearings with Undulating Journal Surface**

M.O.A. Mokhtar, W.Y. Aly, and G.S.A. Shawki

Faculty of Engrg., Cairo Univ., Egypt, Trib. Intl., Cairo Univ., Egypt, Trib. Intl., 17 (1), pp 19-20 (Feb 1984) 7 figs, 13 refs

Key Words: Bearings, Journal bearings, Surface roughness

A journal bearing test rig was designed and constructed to test the behavior of journals with wavy surfaces, the circumferential undulations being varied both in amplitude and in number. Results show that wavy journal surfaces may well enhance the load carrying capacity of a bearing. Moreover, surface undulations are shown to move the journal center locus closer to the load line; causing lower attitude angle.

### 84-1993

**Fluid Film Bearings and Related Rotor Dynamics**

Y. Hori and M. Tanaka

Univ. of Tokyo, Tokyo, Japan, Intl. Fed. of Theory of Machines and Mechanisms, 6th Congress, Tech. Committee on Rotordynamics Session Proc., Indian Inst. of Tech., New Delhi, India, Dec 19, 1983, pp 1-11, 90 refs

Key Words: Bearings, Fluid-film bearings, Journal bearings

It is well recognized that bearings play a vital role in the dynamics of rotor bearing systems. The influence of plain fluid seals on rotordynamics of turbomachinery is also important. This state-of-the-art report summarizes papers published in the last five years classified into eight categories: oil film characteristics, synchronous whirl, stability problems, tilting pad bearings, multilobe bearings, miscellaneous bearings, comparison of bearings of different bore shape, plain fluid seals.

### 84-1994

**Dynamic Analysis of Engine Bearing Systems**

W.A. Welsh and J.F. Booker

Mech. and Aerospace Engrg., Cornell Univ., Ithaca, NY, SAE Paper No. 830065

Key Words: Bearings, Finite element technique, Mobility method

The finite element method of structural analysis and the mobility method of bearing analysis are combined for the computation of main bearing load and displacement cycles (together with such secondary performance variables as film thickness and shaft stress). A numerical example for a production engine illustrates problem-dependent discrepancies between results of present and previous computation methods.

## GEARS

(Also see No. 2093)

### 84-1995

**One Approach on the Axle Gear Noise Generated from the Torsional Vibration**

A. Nakayashiki, K. Kubo, and H. Imanishi

Toyo Kogyo Co., Ltd., Japan, SAE Paper No. 830923 (P-139)

Key Words: Gears, Noise generation, Torsional vibrations

It has been discussed that axle gear noise is largely affected by the torsional vibration of the driveline. In the authors' view, however, the theoretical results do not necessarily coincide with the experimental ones. While theoretical analysis shows no difference in the peak frequency between the acceleration noise and the overrun noise, experiments do show some difference. The authors considered that these phenomena are dependent on the stiffness of the bearings of the pinion and ring gear. Simulating an idealized model which represents the torsional vibration of the driveline, study was made on the analogy of the theoretical results to the experimental ones.

## FASTENERS

**84-1996**

**Dynamic Analysis of Structures with Friction Forces at Sliding Junctures**

D. Hunt, W. Adams, and T. Bock

The Aerospace Corp., El Segundo, CA, J. Spacecraft Rockets, 21 (2), pp 175-179 (Mar/Apr 1984) 11 figs, 4 refs

Key Words: Joints (junctions), Sliding friction, Coulomb friction

The procedure and rationale of two methods for determining the dynamic response of structures with friction forces at sliding junctures is presented. A discrete element model of the structure is used which permits a concise matrix formulation of the problem. The primary contribution in this work is accountability for time-dependent sliding friction forces which are treated as external loads. In one method, the sticking of sliding junctures is simulated by a standard approach used for Coulomb dampers. For the other method, sticking is taken into account for the first time in a discrete element analysis. Numerical results from both methods are compared.

**84-1997**

**Damping at Connection Locations of Machine Frames (Dämpfung in Verbindungsstellen von Maschinengestellen)**

J. Koch, J. Krzyzanowski, and W. Skoczynski

Technological Inst. for Machinery Construction, Polytechnical Inst. of Wroclaw, Poland, Konstruktion, 36 (1), pp 23-29 (Jan 1984) 11 figs, 2 tables, 13 refs

(In German)

Key Words: Joints (junctions), Bolted joints, Damping coefficients, Coulomb friction

The friction mechanism, which affects the design parameter-dependent damping of bolted connections, is described. The measurement of an energy transfer coefficient, as well as of the frequency-amplitude behavior of the test object under harmonic excitation, show that the damping at connection location depends mainly on the microdeflections in the direction tangential to the joint surface. Bolted connections with polished surfaces exhibit a clearly better damping than milled surfaces. The smallest bolt prestress, which provides sufficient connection stiffness and prevents macroslip, yields the highest damping values.

**84-1998**

**In-situ Measurement of Fretting-Wear: A Design Approach**

H. Lyons

Univ. of New Hampshire, SAE Paper No. 831379

Key Words: Fretting corrosion, Wear, Joints (junctions)

Fretting occurs in mechanical or structural joints that were not intended to move, relative to each other, but because of vibrational loads or cyclical deformation, experience minute cyclic relative motion. Fretting-wear develops as a form of wear that retains the majority of the wear debris within the contacting interface. Fretting-wear failure may be defined in functional terms of the normal approach accrued. The magnitude of normal approach due to fretting-wear can be measured in-situ as a function of cycles of operation. These data can be transcribed directly into design curves to enable prediction of impending functional failure in mechanical/structural joints subjected to fretting-wear.

**84-1999**

**An Empirical Method for Estimàting the Fatigue Resistance of Tensile-Shear Spot-Welds**

F.V. Lawrence, Jr., P.C. Wang, and H.T. Corten

Univ. of Illinois at Champaign-Urbana, SAE Paper No. 830035

Key Words: Fatigue life, Welded joints, Joints (junctions)

An empirical method which is based principally on estimates of the fatigue crack initiation life ($N_1$) has been developed which predicts the fatigue resistance of tensile-shear spot welds in the long life regime. The method uses Basquin's law and Peterson's equation to estimate $N_1$ and thus is founded on the fatigue behavior of smooth specimens and modeling of the fatigue notch size effect.

**84-2000**

**A Fracture-Mechanics and System-Stiffness Approach to Fatigue Performance of Spot-Welded Sheet Steels**

J.A. Davidson and E.J. Imhof, Jr.

Res. Lab., U.S. Steel Corp., SAE Paper No. 830034

Key Words: Joints (junctions), Welded joints, Fatigue life, Steel

To improve fuel economy, automotive manufacturers have been gradually incorporating lighter gage, higher strength sheet steels. For the same fatigue loads, the operating stresses of these spot-welded lighter-gage sheets will be greater causing a concomitant reduction in fatigue life. This paper describes the results of a program using fracture-mechanics concepts to determine the fatigue life of spot-welded connections of various stiffness. A model is developed which predicts the fatigue life, and shows that life increases with increasing joint stiffness.

**84-2001**

**Fatigue of Automotive High Strength Steel Sheets and Their Welded Joints**

M. Shinozaki, T. Kato, T. Irie, and I. Takahashi

Res. Labs., Kawasaki Steel Corp., SAE Paper No. 830032

Key Words: Joints (junctions), Welded joints, Steel, Fatigue life

Fatigue properties in various types of high strength steel sheets for automotive use and their spot and arc welded joints were investigated. In steel sheets and strain-aged sheets, fatigue limit stresses and notch sensitivities depend not only on the tensile strength but also the yield strength. Two methods for improving fatigue strength of spot welded high strength steel joints were found.

**84-2002**

**A Review of the Fatigue Properties of Spot-Welded Sheet Steels**

J.A. Davidson

Res. Lab., U.S. Steel Corp., SAE Paper No. 830033

Key Words: Joints (junctions), Welded joints, Steel, Fatigue life

Over the past several years, the automotive industry has used increasing amounts of high-strength sheet steels to reduce vehicle weight for improved fuel economy. This study reviews the spot-weld fatigue performance of uncoated sheet steels with respect to material strength, spot-weld diameter, sheet thickness, and the number and array of spot welds. Models used to describe the state of stress around the spot weld are also reviewed.

**84-2003**

**Notes to the Damping of the Torsional Vibration in the So-Called Immovable Joints**

J. Murín

Inst. of Materials and Machine Mechanics of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 113-119 (1984) 1 fig, 1 ref

(In Slovak)

Key Words: Joints (junctions), Coulomb damping, Torsional vibrations

Resonance dynamical and damping properties of a system with joints are investigated. In the loaded joints microshifts with Coulomb damping occur.

# STRUCTURAL COMPONENTS

## STRINGS AND ROPES

**84-2004**

**Some Topics on Gas Flow: Wave Propagation (Part 1)**

D.H. Daley

Air Force Academy Aeronautics Digest, Rept. No. USAFA-TR-83-15, pp 127-139 (Sept 1983) 9 figs, 1 ref

Key Words: Wave equation, Strings

This article is on the mathematics and physics of wave propagation. It introduces the wave equation by considering the motion of an elastic stretched string.

## BARS AND RODS

**84-2005**

**Separation of Dynamically Induced Low-Frequency Stresses in Rods and Pipes**

G. Pavič

Electrotechnical Institute "Rade Koncar," 41000 Zagreb, Bastijanova bb, Yugoslavia, Exptl. Mech., 24 (1), pp 1-9 (Mar 1984) 12 figs, 3 refs

Key Words: Rods, Pipes (tubes), Wave propagation

Expressions are evaluated with which the separation of oppositely propagating axial-stress components in rods and pipes can be achieved from stress waveforms obtained at different locations on the rod or pipe. The corresponding measurement/processing procedures can produce either the power spectra or the waveforms of these components. Simplifications of basic procedures for waveform evaluation are formulated whenever possible.

## BEAMS

(Also see No. 1878)

**84-2006**

**Free Vibration of Curved Sandwich Beams**

T. Nánási

Inst. of Materials and Machine Mechanics of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnicky Casopis, 35 (1-2), pp 121-137 (1984) 11 figs, 1 table, 12 refs

(In Slovak)

Key Words: Curved beams, Beams, Sandwich structures, Viscoelastic core-containing media, Geometric effects, Natural frequencies, Loss factor

An analysis is given of the free vibrations of a curved three-layered beam with viscoelastic core. Accounting for bending, shear and extensional motion in the energy expressions the Hamilton's principle yields an eighth order governing equation. This is further simplified into sixth order equation by physical arguments.

**84-2007**

**Coupled Wave Motion in Layered Beams with Periodical Stiffeners**

S. Markuš

Inst. of Materials and Machine Mechanics of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 93-111 (1984) 9 figs, 7 refs

(In Slovak)

Key Words: Beams, Layered materials, Flexural waves, Longitudinal waves, Wave propagation, Stiffener effects

The interactions between flexural and longitudinal wave motion in a layered beam with stiffeners attached to the beam at regular intervals are investigated. Relations for propagation constants for coupled waves are derived. It is shown that the propagation constants are highly dependent on coupling between eventual waves.

## COLUMNS

**84-2008**

**A Unified Solution for Various Boundary Conditions for the Coupled Flexural-Torsional Instability of Closed Thin-Walled Beam-Columns**

A. Joshi and S. Suryanarayan

Dept. of Aeronautical Engrg., Indian Inst. of Tech., Bombay, India, Intl. J. Solids Struc., 20 (2), pp 167-178 (1984) 12 figs, 1 table, 8 refs

Key Words: Beam-columns, Columns, Flexural vibration, Torsional vibrations

The problem of coupled flexural-torsional instability of closed thin-walled beam-columns under the combined action of axial loads and equal end moments is studied numerically. The characteristic equations for stability are obtained and the load interaction curves and mode shapes are plotted for various boundary conditions.

**84-2009**
**Cyclic Torsion Tests of Concrete Box Columns**
B. Jakobsen, E. Hjorth-Hansen, and I. Holland
Struc. Engrg. Section, Div. Engrg. and Dev. Dept., Norwegian Contractors, Oslo, Norway, ASCE J. Struc. Engrg., 110 (4), pp 803-822 (Apr 1984) 20 figs, 5 tables, 12 refs

Key Words: Columns, Concretes, Reinforced concrete, Torsional vibrations, Wind-induced excitation, Cyclic loading

Stiffness reduction and material energy dissipation of reinforced concrete box-members have been investigated experimentally under cyclic torsional loading. Six specimens were tested: four in pure torsion and two with axial force in addition to the alternating torque. The amount of reinforcement, the axial load and the load history were varied. The load histories were chosen to simulate the main features of a lightly damped structural response to random environmental loading, such as wind. The specimens were instrumented to trace time-histories of torque, axial load, twisting angle, concrete and reinforcement strains and displacement across cracks. Hysteretic loops are presented in the form of torque-twisting angle curves and strain-torque curves.

## FRAMES AND ARCHES

**84-2010**
**Dynamic Analysis of Arches Using Lagrangian Approach**
A. Raithel and C. Franciosi
Univ. of Naples, Naples, Italy, ASCE J. Struc. Engrg., 110 (4), pp 847-858 (Apr 1984) 9 figs, 2 tables, 3 refs

Key Words: Arches, Natural frequencies, Mode shapes, Earthquake response

Research of frequencies and modes of vibration of an arch is pursued, using the method of reducing the structure to a conservative rigid-elastic system. The role of the reductive matrix of the strain energy is clearly shown. The loads resulting from earthquakes are investigated using dynamic analysis.

## PLATES

**84-2011**
**Effects of Transverse Loading on the Thickness-Shear Resonance Frequencies in Crystal Plates**
Chun-Sing Lam
Ph.D. Thesis, Princeton Univ., 140 pp (1984)
DA8402667

Key Words: Plates, Flexural vibration, Resonant frequencies, Quartz crystals

A system of six two-dimensional equations is derived for the small incremental vibrations superimposed on infinitesimal initial deformation. The terms associated with the third-order elastic constants in the stress-strain relations are retained. These equations govern the six lowest modes of crystal vibrations; namely, flexure, extension, face-shear, thickness-shear, thickness-stretch, and thickness-twist. They are employed in the study of the effects of initial bending on the thickness-shear resonance frequencies of cantilever singly- and doubly-rotated quartz plates. A system of one-dimensional approximate equations is derived to replace the two-dimensional Cauchy's equations for elastic, crystal plates. The equations are used for the study of the deflection and bending stresses in rectangular cantilever plates. Mindlin's two-dimensional first-order equations for crystal plates are replaced by an infinite system of one-dimensional equations. Solutions of initial stresses and displacement due to transverse loading are obtained analytically, which may be regarded as functions of space in the equations of motion of incremental vibrations.

**84-2012**
**Experimental Study on the Symmetric Modes of Vibration of a Four Bolt Clamped Square Plate**
H. Fenech and K. Tran
Univ. of California at Santa Barbara, Appl. Acoust., 17 (3), pp 209-221 (1984) 4 figs, 6 tables, 2 refs

Key Words: Plates, Rectangular plates, Bolted joints, Natural frequencies, Mode shapes, Experimental data

The response of structural components excited by turbulent flow noise depends on the natural resonance frequencies and displacement modes of those components. An experimental program is described which determined those resonance frequencies and modes for a flat plate clamped in the middle of its four sides and also for the case when one of the four bolts had failed. Thirty-three resonances in the range 30·5 to 736 Hz have been identified for the four-bolt normal operation and forty-two in the range 12·5 to 496·1 Hz for the three-bolt accidental situation.

## SHELLS

**84-2013**
**Blast Loading of a Spherical Container Surrounded by an Infinite Elastic Medium**
L.A. Glenn and R.E. Kidder

Lawrence Livermore Lab., Livermore, CA, ASME Paper No. 83-WA/APM-17

Key Words: Tanks (containers), Shells, Spherical shells, Elastic media, Impulse response

Closed-form solutions are derived for the response of a spherical elastic shell, surrounded by a different elastic medium of infinite extent, and subjected to Heaviside or impulsive loading. The results are compared with earlier solutions in which the surrounding medium was a fluid.

## PIPES AND TUBES

(Also see No. 2005)

**84-2014**

**Dynamic Motions of Marine Pipelines on the Ocean Bottom**

A.J. Healey and Y.G.T. Seo

Brown and Root, Inc., Houston, TX 77001, J. Energy Resources Tech., Trans. ASME, 106 (1), pp 65-69 (Mar 1984) 10 figs, 8 refs

Key Words: Pipelines, Underwater pipelines, Wave forces, Hydrodynamic excitation

A dynamic model of a pipeline portion exposed to wave and current forces for the purpose of assessing on bottom stability is described. When an exposed span is marginally stable, and trenching not possible, some motion in the presence of an extreme wave may be tolerable. Analysis of a particular case shows that a few feet of movement would occur with a 100-yr wave. The final configuration after passage of one wave is given by the analytical model and it is predicted that a moderate residual stress would be induced.

**84-2015**

**Damping Studies**

A.G. Ware

EG and G Idaho, Inc., Idaho Falls, ID, Rept. No. EGG-M-20683, CONF-8310143-34, 10 pp (1983) (NRC Water Reactor Safety Research Information Mtg., Gaithersburg, MD, Oct 14, 1983)
DE84002216

Key Words: Pipes (tubes), Steel, Supports, Damping coefficients

Two series of vibration tests on 3- and 8-inch diameter carbon steel pipes with different support configurations were conducted to determine the damping characteristics of each. The purposes of the tests were to achieve a better understanding of the physical nature of piping system damping, to determine typical values of the various supports, and to supply data for use in the US Nuclear Regulatory Commission (NRC) and Pressure Vessel Research Committee of the Welding Research Council pipe damping programs. The final goal of these programs is to ascertain whether the current NRC guidelines for piping system damping values can be increased, thereby requiring less seismic supports and making the systems less susceptible to thermal stress failure, less costly, and more reliable.

**84-2016**

**A Theoretical Model for the Cross-Flow Induced Fluid-Elastic Instability in Heat Exchanger Tube Bundles**

J.H. Lever

Ph.D. Thesis, McMaster Univ., Canada, 1983

Key Words: Heat exchangers, Tube arrays, Fluid-induced excitation

A simple theoretical model has been developed from first principles for the cross-flow induced fluid-elastic instability in heat exchanger tube bundles. A series of experiments were conducted to verify the basic assumption that only a single tube need be modeled in a flow channel which preserves the basic geometry of the array. The mechanism of dynamic instability is found to be one of flow redistribution due to transverse tube motion and a phase lag resulting from fluid inertia. Static instabilities in both streamwise and transverse directions are also predicted, but at higher reduced flow velocities than the transverse dynamic instability.

**84-2017**

**Dynamics of Tubes in Fluid with Tube-Baffle Interaction**

S.S. Chen, J.A. Jendrzejczyk, and M.W. Wambsganss

Argonne National Lab., Argonne, IL, Rept. No. ANL-83-72, 89 pp (Sept 1983)
DE84001452

Key Words: Tube arrays, Fluid-induced excitation

Three series of tests are performed to evaluate the effects of tube to tube-support-plate (TSP) clearance on tube dynamic characteristics and instability phenomena for tube arrays in crossflow. Test results show that, for relatively large clearances, tubes may possess TSP-inactive modes in which the tubes rattle inside some of the tube-support-plate holes, and that the natural frequencies of TSP-inactive modes are lower than those of TSP-active modes, in which the support plates provide knife-edge type support.

## DUCTS

**84-2018**

**Acoustic Shocks in a Variable Area Duct Containing Near Sonic Flows**

S.I. Hariharan and H.C. Lester

NASA Langley Res. Ctr., Hampton, VA, Rept. No. REPT-83-64, NASA-CR-17224, 21 pp (Dec 1983) N84-15897

Key Words: Ducts, Variable cross section, Shock waves, Acoustic waves

Acoustic shock waves in a variable area duct which contains near sonic flows are considered. The problem is modeled after an aeroengine inlet. Area variation of a duct and high Mach number mean the flow reduces acoustical energy yielding substantial noise reduction. One possible reason for this is acoustic shock. The use of an explicit accurate numerical method which captures shocks is described. Comparison of the results are made with an existing asymptotic theory for Mach numbers close to unity. When shock occurs reduction of sound pressure levels are shown by example.

## BUILDING COMPONENTS

**84-2019**

**Effects of Bare and Cased Explosives Charges on Reinforced Concrete Walls**

H. Hader

Ernst Basler & Partners, Consulting Engineers, 8029 Zurich, Switzerland, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 221-226, 8 figs

Key Words: Explosion effects, Walls, Reinforced concrete

This paper represents a summary of an extensive investigation concerning the local effects of bare and cased explosives charges on reinforced concrete walls. The investigation includes a literature search as well as several test series. As a main result, charts for the prediction and comparison of the effects of bare and cased explosives charges are developed.

**84-2020**

**Simulation of Pressure Waves and Their Effects on Loaded Objects. Part 1: Outlining the Problem, Description of the Simulation Device**

G. Hoffmann and K. Behrens

Ernst-Mach-Institut, Fraunhofer-Institute f. Kurzzeitdynamik, 7800 Freiburg, Fed. Rep. Germany, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 204-209, 9 figs

Key Words: Walls, Masonry, Shock waves

Blast waves generated by detonations of HE or fuel-air-mixtures are characterized by their peak pressure and their overpressure phase duration; i.e., by two parameters. But normally unconfined fuel-air-mixtures will deflagrate generating a pressure time history of a quite different shape. In contrast there is a relatively slow pressure rise up to a peak value followed by a sudden decay into a suction phase the minimum value of which is of the order of the overpressure peak value. The overall duration of this pulse is comparatively long. For such a pulse there are more than two parameters necessary for a complete description. Despite the small peak pressure value these waves proved rather dangerous as numerous accidents have shown. Therefore it is desirable to get some insight into the destructive mechanism of these pulses. To be able to do that a special simulation device was developed which is described.

**84-2021**

**Simulation of Pressure Waves and Their Effects on Loaded Objects. Part II: Experiments and Calculations; Destruction Curves**

K. Behrens and G. Hoffmann

Ernst-Mach Institut, Fraunhofer-Institut f. Kurzzeitdynamik, 7800 Freiburg, Fed. Rep. Germany, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 210-215, 13 figs, 11 refs

Key Words: Walls, Masonry, Shock waves

Experiments to investigate the response of model planes and model brick walls to deflagrative pressure pulses were carried out in the deflagration simulator described in part 1 of this paper. Calculations based on a one-degree-of-freedom oscillator model were compared with the test results. They led to a set of curves in the scaled pressure impulse plane from which isodamage or destruction curves were derived for the specific objects under investigation. These curves differ from the well known P-I-curves for objects under blast load conditions in that the curves for deflagrative loading split up into two branches in the region of small impulses. This is due to the significant underpressure phase of the deflagrative pulse which causes resonance effects in the response of the loaded object.

**84-2022**

**Response of Cable Roofs to Wind**

I.D. El-Ashkar

Ph.D. Thesis, Univ. of Western Ontario, Canada, 1983

Key Words: Roofs, Cable stayed structures, Wind-induced excitation

A nonlinear solution is formulated for a single hanging cable and flat rectangular and circular cable roofs under the effect of the initial tension and the applied loads. The solution is based on a small strain large displacement theory.

# ELECTRIC COMPONENTS

## CONTROLS (SWITCHES, CIRCUIT BREAKERS)

**84-2023**

**Seismic Analysis of a Nonlinear Airlock System**

S.N. Huang

Hanford Engrg. Dev. Lab., Richland, WA, Rept. No. HEDL-SA-2839, CONF-830607-29, 29 pp (Jan 1983) (ASME Pressure Vessel and Piping Conf., Portland, OR, June 19, 1983)
DE84001493

Key Words: Actuators, Seismic analysis

The containment equipment airlock door of a test facility utilizes screw-type actuators as a push-pull mechanism for closing and opening operations. Special design features were used to protect these actuators from pressure differential loading. These made the door behave as a nonlinear system during a seismic event. Seismic analyses, utilizing the time history method, were conducted to determine the seismic loads on these screw-type actuators. Several sizes of actuators were examined. Procedures for determining the final optimum design are discussed in detail.

# DYNAMIC ENVIRONMENT

## ACOUSTIC EXCITATION

**84-2024**

**Some Stochastic Considerations in Theoretical Formulation of Acoustic Intensity Method Using Two Microphones**

G.P. Mathur

Structural Dynamics R&D, Beech Aircraft Corp., Wichita, KS, SAE Paper No. 830769

Key Words: Stochastic processes, Acoustic intensity method, Two microphone technique

The theoretical formulation of the cross-spectral density formula based on finite difference approximations is examined in light of certain stochastic considerations. General expressions for mean square errors involved in estimating acoustic pressure and particle velocity for determining acoustic intensity are derived. It is shown that estimation of particle velocity using finite difference approximation is, in particular, not satisfactory even for very small microphone spacings.

**84-2025**

**Measurement of the Sound Insulation of Small Enclosures**

H. Jonasson and L. Eslon

Statens Provningsanstalt, Boras, Sweden, Rept. No. SP-RAPP-1982-30, 124 pp (Apr 1983)
PB84-148469

Key Words: Enclosures, Reverberation chambers, Acoustic absorption

This Nordtest project has resulted in a proposal for Nordtest method for the measurement and rating of small (less than 2 cubic meters) enclosures. The proposal is based on either the measurement of the insertion insulation for sound power in a reverberation room with some type of reference sound source or on reciprocal measurements, that is the sound pressure level difference between an outer diffuse sound field and an inner field inside the enclosure. Measurements have indicated that these two methods are equivalent if the enclosure has absorbing interior surfaces and not too large openings.

**84-2026**

**A Study of Barriers in Enclosures by a Ray-Tracing Computer Model**

G. Benedetto and R. Spagnolo

Istituto Elettrotecnico Nazionale Galileo Ferraris, Corso Massimo d'Azeglio, 42-10125 Torino, Italy, Appl. Acoust., 17 (3), pp 183-199 (1984) 9 figs, 25 refs

Key Words: Enclosures, Noise barriers, Sound waves, Wave attenuation

The theoretical study of the behavior of barriers in enclosures is much more complicated than that of barriers in the free field. In the latter case one has to take into account the sound energy reflected at the boundary surface of the enclosure. The barrier-absorption joint effect has to be considered in defining the barrier sound attenuation. From this point of view, the barrier attenuation also depends on the enclosure shape and proportions. A numerical method is suggested, based on a ray-tracing technique, in which the concepts inherent in Keller's theory of diffraction are included. The results of some simulation examples are reported.

**84-2027**

**Acoustic Envelope Having Minimal Vibration and Flow Induced Noises**

H.A. Miller and C.S. Nichols

Dept. of the Navy, Washington, DC, U.S. Patent 4 402 069

Key Words: Noise reduction, Tubes

An acoustic envelope is provided which may include a tubular sheath which is mounted about a conducting element. The tubular sheath has inner and outer tubular portions which are integral with respect to one another. The acoustic envelope further includes a plurality of non-elastic strands which extend longitudinally along the sheath between the inner and outer tubular portions and which are bonded thereto. The tubular sheath is constructed of a material which optimally minimizes vibration induced noise and flow induced noise when the line array is towed through the water.

**84-2028**

**Closing the Door on Noise**

T.F. Meinhold, Sr. Editor

Plant Engrg., 38 (13), pp 54-63 (June 14, 1984) 2 figs, 1 table

Key Words: Noise reduction, Acoustic absorption, Absorbers (materials)

A typical noise control product guide is provided. The information focuses on the recommended uses and performance data as supplied by the manufacturers. It makes no differentiation between materials, components, or systems.

## SHOCK EXCITATION

(Also see Nos. 1902, 2019, 2020, 2112)

**84-2029**

**An Experimental Method for Determining the Dynamic Contact Law**

J.F. Doyle

Dept. of Aeronautics and Astronautics, Purdue Univ., West Lafayette, IN 47906, Exptl. Mech., 24 (1), pp 10-16 (Mar 1984) 9 figs, 6 refs

Key Words: Impact force

An experimental method is investigated whereby the strain response from an impacted beam is sufficient to determine the contacting force. Once the force is known, it is shown how the contact law can be determined. Experimental results for an impacted aluminum beam are demonstrated.

**84-2030**

**The Lumped Parameter Method for Elastic Impact Problems**

Y. Lee, J.F. Hamilton, and J.W. Sullivan

Pennsylvania State Univ., State College, PA, ASME Paper No. 83-WA/APM-10

Key Words: Impact response, Lumped parameter method, Timoshenko theory

Transverse impact problems have recently been solved by several different methods including Timoshenko's integral equation method, the energy method, and the finite element method. A lumped parameter method is presented for impact analysis which is attractive for the solutions of impact of complex bodies.

**84-2031**

**Analysis of Containment Rings for Flywheel Burst Protection**

C.W. Bert

Univ. of Oklahoma, Norman, OK, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 130-133, 15 refs

Key Words: Protective shields, Flywheels, Blast response, Hertzian contact

This paper is concerned with the analysis of Hertzian impact of a band-supported, thick-rim flywheel against an elastic containment ring. The following topics are addressed: consideration of probable failure mode of the flywheel, estimation of impact velocity, prediction of maximum conditions at contact, prediction of the maximum bending stress in the impulsively loaded containment ring, and sample calculation for a proposed containment ring.

**84-2032**

**Rapid Runway Cutting with Shaped Charges**

C.E. Joachim

U.S. Army Engineer Waterways Experiment Station, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 32-36, 10 figs, 1 table, 1 ref

Key Words: Runways, Concretes, Cutting, Explosives

Removal of large, partially damaged, concrete runway slabs is a major element in the time required to perform a runway repair operation. The results of field tests designed to evaluate the runway cutting abilities of standard and linear shaped charges are presented. A series of 25 runway cutting tests was conducted on the 1-ft-thick (4 in of asphalt + 8 in of concrete) undamaged taxiway segments constructed for a recent Air Force test program.

**84-2033**

**Interaction of High-Velocity Aluminum Shaped-Charge Jets with Finite Steel and Concrete Targets**

D.K. Davison

Physics International Co., San Leandro, CA, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 2, pp 43-47, 3 figs, 1 table

Key Words: Penetration, Projectile penetration, Plates, Steel, Concretes

Experiments were performed with 6.8-cm-diameter shaped charges that produced jets with tip velocities in excess of 1.0 cm/$\mu$s. The charges were fired at short standoff into 1-inch steel and 10-inch reinforced concrete targets, and the jets were radiographed to observe their shapes and the distributions of mass and velocity. The experiments indicated that a mushroom-shaped jet tip can be effective in perforating hardened steel plates by the plugging process. Such jets can also be effective in perforating very thick concrete targets.

**84-2034**

**Penetration Equation from Steel, Aluminum, and Titanium Plates by Deforming Projectiles at Obliquity**

J.S. O'Brasky and T.N. Smith

Naval Surface Weapons Ctr., Weapons Dev. Branch, Dahlgren, VA, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 2, pp 48-52, 4 figs, 11 refs

Key Words: Plates, Steel, Aluminum, Projectile penetration, Penetration

A similitude equation is offered for the penetration of steel, aluminum, and titanium plates at obliquities up to 70° by nondeforming steel projectiles. The proposed equation is confidenced and compared to the accuracy achieved in single projectile-single material relationships.

**84-2035**

**Concrete Penetration and Ricochet Testing of Two Projectile Types**

R.D. Szczepanski and J.A. Collins

Orlando Technology, Inc., Shalimar, FL, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 2, pp 35-42, 10 figs, 4 refs

Key Words: Projectile penetration, Penetration, Concretes

The purpose of the work was to develop penetration/ricochet data for two projectiles launched against 5,000 psi concrete targets and, in addition, to measure the axial stress on the nose of a projectile during concrete penetration.

**84-2036**

**High Velocity Penetration into Fibre-Reinforced Concrete Materials -- Protection of Buildings**

W.F. Anderson, A.J. Watson, and P.J. Armstrong

Dept. of Civil and Struc. Engrg., Univ. of Sheffield, UK, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 17-22, 5 figs, 7 refs

Key Words: Concretes, Reinforced concrete, Impact response, Projectile penetration

Fibre-reinforced concrete suitable for spraying onto existing structures is examined to assess its resistance to penetration by 7.62 mm diameter armor piercing projectiles. A major test program is carried out to examine the influence of aggregate type and fiber type. For each aggregate/fiber combination a statistical method is used to plan test series which will lead to optimization of the concrete in terms of water/cement ratio, fiber content and aggregate/cement ratio.

**84-2037**

**Analytical and Experimental Studies on Penetration into Geological Targets**

M.J. Forrestal, D.B. Longcope, and L.M. Lee

Sandia National Labs., Albuquerque, NM 87185, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 23-26, 4 figs, 12 refs

Key Words: Impact response, Projectile penetration

Recent analytical and experimental work on penetration into geological targets is summarized. Results from several elastic-plastic type theoretical models which predict forces on penetrators for normal impact into dry porous rock, concrete, and sea ice targets are presented and compared with measurements from field tests. Rigid-body acceleration data from newly developed laboratory scale experiments for impact velocities between 0.2 and 1.2 km/s are also presented.

**84-2038**

**Penetration Behaviour of Highly Deformable Projectiles in Concrete Slabs**

M. Hulsewig, E. Schneider, and J. Stilp

Terminal Ballistics and Impact Physics Div., Ernst-Mach-Institut, Freiburg, Fed. Rep. Germany, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 27-31, 9 figs, 3 refs

Key Words: Slabs, Concretes, Impact response, Penetration, Projectile penetration

Investigations of the penetration behavior of deformable projectiles in reinforced concrete slabs show that classical penetration formulas developed for rigid projectiles are not applicable to describe the penetration at impact velocities between 100 and 400 m/s. The measured crater depths are smaller; the divergence increases with higher velocities, because the projectile deformation itself consumes a considerable amount of the kinetic energy of the projectile.

**84-2039**

**Calculational Evaluation of the Inclusion Effects on Stress Gage Measurements in Rock and Soil**

A.L. Florence, D.D. Keough, and P. Mak

SRI International, Menlo Park, CA 94025, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 7-11, 9 figs

Key Words: Vulnerability, Blast response, Measurement techniques, Soils, Rocks

Explosion-induced stress waves in rocks and soils are frequently measured by flatpack stress gages grouted in boreholes. The stress gage measurements differ from the free-field stresses if the grout forms on inclusion because of a mismatch of material properties or inadequate bonding with the medium. Calculational results are presented for a tuff medium to illustrate inclusion effects in elastic and elastic-plastic regimes. The main effect occurs if the inclusion-medium bonding is inadequate.

**84-2040**

**Free-Field Ground Shock Pressures from Buried Detonations in Saturated and Unsaturated Soils**

P.S. Westine and G.J. Friesenhahn
Southwest Res. Inst., San Antonio, TX, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 12-16, 4 figs, 3 refs

Key Words: Underground explosions, Ground shock

Free-field ground shock pressures at various distances from the buried detonation of high-explosive charges, mortar and artillery rounds, and large bombs were measured. This paper presents an empirical solution capable of predicting these pressures in unsaturated soils. In saturated soils, a very different energy dissipation process occurs which is predicted by modifying a hydrodynamic solution, and comparing it to tests on bombs in saturated soils.

**84-2041**

**Ground Shock from Penetrating Conventional Weapons**

J.L. Drake and C.D. Little, Jr.
U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 1-6, 3 figs, 1 table, 15 refs

Key Words: Explosions, Weapons effects, Ground shock

Results of an analysis of ground shock data from more than one hundred explosion tests conducted in soil over the past 35 years are presented. Burst positions varied from fully buried to contact detonations in soil and for shallow depths into concrete protective overlays. Soil conditions ranged from loose dry sand to saturated clay. Empirical equations are presented that predict the magnitude and time histories of the expected stresses and ground motions as a function of burst position, soil indices and burster layer thickness.

**84-2042**

**Predicting Response of Munitions to Massive Secondary Fragment Impact -- A Proposed Analytical Method**

A. Longinow, E.E. Hahn, H. Napadensky, and E. Swider
Illinois Inst. of Tech., Chicago, IL, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 44-48, 8 figs, 3 refs

Key Words: Weapons systems, Ammunition, Explosives, Impact response

An analytic method is presented for studying the mechanisms that lead to the detonation of cased munitions filled with molten explosives when impacted by large concrete fragments, representing failed wall sections. This is a single degree of freedom dynamic structural analysis method which makes use of predetermined, nonlinear load-deflection characteristics of the shell casing. The method was applied to predict the pressure-time history in the molten explosive when subjected to impact.

**84-2043**

**Modeling the Burn-to-Violent Reaction to Simulate Impact-Damaged GP Warheads**

H. Krier, M. Dahm, and P.B. Butler
Univ. of Illinois at Urbana-Champaign, IL 61801, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 37-43, 11 figs, 3 refs

Key Words: Weapons systems, Ammunition, Explosives, Impact response

Impact forces from hardened, concrete targets to a general purpose warhead (bomb) can in some cases cause outer-case failure and breakup of the high explosive filler prior to fuse initiation. The detonation that is expected to occur under reliable penetration and for totally confined conditions can be reduced to that of a rapid deflagration with reduced damage to the target/structure. This paper presents the solution to the dynamic equations of motion for gas-particle systems that simulate in one-dimension, the high pressure, subdetonation speed reactions in such beds of fragmented high explosive.

**84-2044**

**The Effects of Indirect-Fire Munitions on Framed Structures**

B.L. Morris and P.H. Zabel

*Southwest Res. Inst.*, San Antonio, TX, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 155-158, 2 tables, 17 refs

Key Words: Framed structures, Steel, Reinforced concrete, Weapons effects, Blast response

An effectiveness evaluation of the use of indirect-fire munitions against steel- and reinforced concrete-framed structures in an urban environment is reported. Effects include collapse of columns due to lateral blast loads, crushing of columns by vertical blast loads, response of interior and exterior walls to blast and fragments, response of personnel to blast overpressures and wall debris, and the formation and location of rubble caused by the detonations of these munitions.

**84-2045**

**Comparison of Predictive Methods for Structural Response to HE Blast Loads**

W.T. Char and M.M. Dembo

*U.S. Army Corps of Engineers, Huntsville, AL*, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 188-192, 10 figs, 1 table, 6 refs

Key Words: Explosion effects, Damage prediction, Aerial explosions

Numerous methods for predicting structure response to airblast caused by HE explosions were developed during the last twenty years. The rigor, complexity and sophistication of the methods are known to cover a wide spectrum. Some less complex but widely accepted methods are examined, assessed, and discussed relative to their degree of conservatism. To support their assessment, the authors critically examined the structural design parameters used in the predictive methods.

**84-2046**

**Gas Pressure Loads from Explosions within Vented and Unvented Structures**

W.E. Baker, J.C. Hokanson, E.D. Esparza, and N.R. Sandoval

*Southwest Res. Inst.*, San Antonio, TX, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 177-181, 8 figs, 13 refs

Key Words: Explosion effects, Enclosures

Gas pressures from explosions within enclosures, as opposed to shock loads, can be the dominant loads causing structural failure. This paper reviews test results and prediction methods for gas pressures for many types of internal explosions including high explosives, high explosives plus combustibles, gas mixtures and dust suspensions.

**84-2047**

**Combination of Earthquake Direction Effects**

A. Morrone

Advanced Energy Systems Div., Westinghouse Electric Corp., Madison, PA, Rept. No. CONF-830805-61, 18 pp (1983) (Intl. Conf. on Struc. Mech. in Reactor Tech., Chicago, IL, Aug 22, 1983)
DE84001848

Key Words: Seismic response, Root mean squares

The correct application of the square root of the sum of the squares (SRSS) rule is presented for obtaining the combined responses of a subsystem to seismic excitations given by orthogonal earthquake components represented by system response spectra. Alternate methods of applying the SRSS, which are sometimes used either for simplicity or due to different interpretation, are evaluated and compared with the correct method.

**84-2048**

**On Syntheses of Ground Motions from Earthquakes**

D.A. Sotiropoulos

Ph.D. Thesis, Univ. of California, San Diego, CA, 125 pp (1983)
DA8401885

Key Words: Earthquakes, Ground motion

A study is made of the different methods to synthesize ground motions from a fault rupturing in shear. The free-field motion is given by an integral over space and time of the Green's functions and slip. The problems involved in carrying out the numerical integrations are analyzed. The dependence of the Green's functions on epicentral distance, depth and frequency is studied. Based on the properties of the Green's functions, in a multilayered viscoelastic half-space, a numerical integration scheme in the frequency domain is developed. The effect of integration step on the response is examined.

## VIBRATION EXCITATION

**84-2049**

**A Periodically Forced Impact Oscillator with Large Dissipation**

S.W. Shaw and P.J. Holmes

Cornell Univ., Ithaca, NY, ASME Paper No. 84-WA/APM-23

Key Words: Oscillators, Periodic excitation

Considered is the simple harmonic oscillator with harmonic excitation and a constraint that restricts motions to one side of the equilibrium position. Thus, on the achievement of a specified displacement, the direction of motion is reversed using the simple impact rule.

**84-2050**

**Chatter in Wet Brakes**

T.V. Friesen

Chevron Res. Co., SAE Paper No. 831318

Key Words: Brakes (motion arresters), Tractors, Chatter, Self-excited vibrations, Measurement techniques

The wet brakes used in wheeled tractors often produce noise and vibration on engagement. This vibration, normally termed "chatter," is often attributed to stick-slip. This paper discusses how a negatively sloped friction-velocity curve and/or brake geometry can induce these self-excited vibrations. Methods of measuring brake chatter are also discussed.

**84-2051**

**Characterizing the Vibratory Output of a Multi-terminal Machine and Predicting the Vibration of the Supporting Structure**

A.O. Sykes

Resonics, Inc., Washington, DC, SAE Paper No. 831433

Key Words: Machinery-induced vibrations, Vibration prediction, Vibration control

In predicting the effectiveness of quieting measures for reducing machine-induced structural vibration, it is necessary to know the vibratory output of the machine and the dynamical properties of both the machine and the supporting structure. In many vibration reduction problems, even if the causes of the vibratory output of the machine are known (e.g., unbalance, combustion processes, friction, fluid-flow), the magnitudes of the excitations, their points of application, and the transfer functions thence to the machine output terminals (the mounting points) are unknown; hence, prediction of vibratory output is difficult. A method is proposed for predicting structural vibration, and the effectiveness of quieting measures, which would utilize data available at the output terminals of the machine, and input terminals of the supporting structure.

**84-2052**

**Parametric Instabilities**

Z. Parszewski

Univ. of Melbourne, Melbourne, Australia, Intl. Fed. of Theory of Machines and Mechanisms, 6th Congress, Tech. Committee on Rotordynamics Session Proc., Indian Inst. of Tech., New Delhi, India, Dec 19, 1983, pp 12-20, 15 figs, 18 refs

Key Words: Parametric vibration

Variation of some parameters of machine systems which may introduce dynamic phenomena, called parametric vibrations, are discussed.

# MECHANICAL PROPERTIES

## DAMPING

(Also see Nos. 1895, 1940)

**84-2053**

**On a Magnetic Damper Consisting of a Circular Magnetic Flux and a Conductor of Arbitrary Shape. Part 1: Derivation of the Damping Coefficients**

K. Nagaya and H. Kojima

Gunma Univ., Kiryu, Gunma 376, Japan, J. Dynam. Syst., Meas. Control, Trans. ASME, 106 (1), pp 46-51 (Mar 1984) 4 figs, 1 table, 15 refs

Key Words: Magnetic damping, Damping coefficients

Theoretical results for finding the damping coefficients of a magnetic damper consisting of a circular magnetic flux and an arbitrarily shaped conductor have been obtained. In the analysis the exact solution in polar coordinates for the governing equation of the electromagnetic fields is utilized. The boundary condition for arbitrarily shaped boundaries of the conductor is satisfied directly by means of the Fourier expansion collocation method.

**84-2054**

**On a Magnetic Damper Consisting of a Circular Magnetic Flux and a Conductor of Arbitrary Shape. Part II: Applications and Numerical Results**

K. Nagaya

Gunma Univ., Kiryu, Gunma 376, Japan, J. Dynam. Syst., Meas. Control, Trans. ASME, 106 (1), pp 52-55 (Mar 1984) 8 figs, 4 tables, 1 ref

Key Words: Magnetic damping, Damping coefficients

A method of numerical calculation for obtaining the damping coefficients and potential fields is presented for magnetic dampers utilizing theoretical results given in Part I. The study is concerned with dampers consisting of the following conductors and magnetic fluxes: a rectangular conductor and an eccentric circular flux, a circular conductor and an eccentric circular flux, and polygonal conductors of various shapes and a concentric circular flux. Numerical results for the damping coefficients, and potential lines of the magnetic fields are obtained for these dampers.

**84-2055**

**Effects of Thermal Damping on the Dynamic Response of a Hydraulic Motor-Accumulator System**

A. Pourmovahed and D.R. Otis

Univ. of Wisconsin-Madison, WI 53706, J. Dynam. Syst., Meas. Control, Trans. ASME, 106 (1), pp 21-26 (Mar 1984) 8 figs, 16 refs

Key Words: Damping effects, Temperature effects, Energy dissipation, Hydraulic systems

A hydraulic accumulator is often modeled as a gas spring following a polytropic process, but this fails to properly account for the dissipative effects of heat transfer which produce damping and phase shift in the dynamic behavior. A thermal time constant can properly characterize the heat transfer between the charge gas and the accumulator walls, and it is shown that for the linearized case the accumulator becomes equivalent to the anelastic model. The transfer function for the accumulator is derived, and the mathematical solution is presented for a hydraulic accumulator coupled to the inlet of a hydraulic motor where the load force is subject to a small, sinusoidal variation with time. Experimental data are presented to show that the accumulator can be accurately modeled using a thermal time constant, and the anelastic model would adequately describe the accumulator for the case of small perturbations.

## FATIGUE

**84-2056**

**Service Fatigue Life**

M. Bílý, V. Kliman, and V.T. Troščenko

Inst. of Materials and Machine Mechanics of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 19-37 (1984) 5 figs, 2 tables, 10 refs

(In Slovak)

Key Words: Fatigue life

The paper is concerned with methods of the theoretical and experimental estimation of service fatigue life as one of the most important properties of the service reliability. The authors assess possibilities of an experimental fatigue life verification under simulated service loading in the form of a set of blocks of harmonic cycles or individual cycles, or in the form of random processes with various statistical characteristics. Both stationary and non-stationary properties of service random processes are taken into account. Methods of theoretical fatigue life estimation are analyzed that are based on up-to-date hypotheses of fatigue damage accumulation, respecting cyclic deformation material properties and random character of a service process.

**84-2057**

**Strain-Cycle Fatigue of Sheet and Plate Steels I: Test Method Development and Data Presentation**

G.A. Miller and H.S. Reemsnyder

Res. Dept., Bethlehem Steel Corp., SAE Paper No. 830175

Key Words: Steel, Fatigue life

A method was developed for performing strain-controlled fatigue tests on steel specimens with thickness $<$ 0.1 inch. Data generated using this method were found to be consistent with published results for steels of similar strength and thickness. Geometric variables; i.e., gage section width and area, gage length, etc., have little effect on valid fatigue results (excluding buckling, excessive bending, and out-of-gage length failures). However, increased gage length or specimen width increase the likelihood of invalid results.

**84-2058**

**Strain-Cycle Fatigue of Sheet and Plate Steels III: Tests of Notched Specimens**

G.A. Miller and H.S. Reemsnyder

Res. Dept., Bethlehem Steel Corp., SAE Paper No. 830176

Key Words: Steel, Fatigue life

The effect of steel grade on reversals to crack initiation in notched specimens $2N_i$ essentially reflected differences in tensile strength. The various predictive models studied (local strain, nominal stress, empirical) gave similar results in terms of the variability in estimates of $2N_i$ and the relation between the predicted and observed values.

**84-2059**

**Fatigue Properties of Renitrogenized and Dual Phase Steels**

R. Pietrowski, W.F. Gasse, and W.D. Kenny

Dofasco Inc., SAE Paper No. 830171

Key Words: Steel, Fatigue life

One of the more effective ways of improving automobile fuel efficiency is by reducing vehicle weight. This can be accomplished through the use of higher strength, lighter gauge steels. This study concentrates on two such steels (renitrogenized and dual phase) that potentially could be used in some fatigue applications. Three dual phase steels with different monotonic strengths were tested, as was some dual phase which was exposed to undervehicle corrosion. Two renitrogenized steels were also tested, as well as a mild steel of similar carbon content.

**84-2060**

**Notch Fatigue Strengths of Several High-Strength Low-Alloy Sheet Steels**

S.P. Bhat

Inland Steel Res. Labs., SAE Paper No. 830174

Key Words: Steel, Fatigue life

Most structural components contain geometric discontinuities or notches. Over the years, several approximate methods have been developed to relate the remote stress to the local stress and the local strain under conditions of localized plastic yielding during fatigue. A new method of computing the fatigue strength reduction factor in the presence of a notch has been developed. The method estimates the notch root stresses from strain controlled fatigue data for any given life. The application of this technique is illustrated by presenting data for several HSLA steels.

**84-2061**

**Strain-Cycle Fatigue of Sheet and Plate Steels II: Some Practical Considerations in Applying Strain-Cycle Fatigue Concepts**

G.A. Miller and H.S. Reemsnyder

Res. Dept., Bethlehem Steel Corp., SAE Paper No. 830173

Key Words: Steel, Fatigue life

Variability in published strain-cycle fatigue data was essentially independent of grade and strain amplitude for life $< 2\times10^6$ reversals. Correlations between tensile properties and strain-cycle fatigue parameters were either not statistically significant or so highly variable as to be of doubtful practical importance. Present findings emphasize the need for caution in estimating life when data are unavailable since such estimates encompassed a range in life 10 to 100 times greater than was actually observed.

**84-2062**

**Improving Corrosion Fatigue Resistance of Aluminum Alloys**

V.I. Birss, R.B. Lidstone, and M. Zamin

Kingston Labs., Alcan International Ltd., SAE Paper No. 830129

Key Words: Fatigue life, Aluminum, Corrosion fatigue

This paper is concerned with the influence of the environment on the fatigue behavior of welded aluminum structures and describes methods that have been evolved to improve this behavior. Successful approaches include the application of particular organic coatings and the use of brush peening and combination of the two methods which proved to be cumulatively beneficial.

**84-2063**

**Fatigue/Impact Studies in Laminated Composites**

V.S. Avva

North Carolina A & T State Univ., 1601 Market St., Greensboro, NC 27411, Rept. No. AFWAL-TR-83-3060, 152 pp (May 1983)

Key Words: Fatigue life, Impact response, Layered materials, Composite materials

This study primarily addresses the behavior of the laminated fiber composite materials subjected to low velocity projectile impact and or cyclic loading.

## ELASTICITY AND PLASTICITY

**84-2064**

**A Plastic-Fracture Model for Concrete Materials**

W.F. Chen and T.Y.P Chang

Purdue Univ. West Lafayette, IN, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 56-64, 4 figs 18 refs

Key Words: Concretes, Fracture properties

Recent research in structural concrete under static and dynamic loading has been moving toward the development of three-dimensional stress-strain relations based on the principles of plasticity as well as elasticity Although significant progress in this area has been made in recent years, no unified treatment of the various existing mathematical models of concrete has been attempted from which a comprehensive elastic-plastic-fracture stress-strain relationship for concrete can be formulated This unified approach is attempted in the present work. In this theoretical development, the five-parameter failure surface of Willam-Warnke model, the technique of mixed hardening for cyclic loading, the concept of crushing coefficient and the dual criterion for crushing, cracking, and mixed types of failure of concrete will be considered as the basis for this comprehensive development.

**84-2065**

**Microplane Model for Fracture Analysis of Concrete Structures**

Z.P. Bazant and B.H. Oh

Nort ıwestern Univ., Evanston, IL 60201, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol 1, pp 49-55, 3 figs, 2 tables, 23 refs

Key Words: Concretes, Fracture properties

Dynamic fracture analysis of concrete structures necessitates a triaxial stress-strain relation that describes gradual strain-softening with reduction of tensile stress to zero. A new model which does that and is applicable under general loading, including rotating principal stress directions, is proposed. It is based on accumulating stress relaxations due to microcracking from the planes of all orientation within the microstructure. Comparisons with tensile test data are given.

## WAVE PROPAGATION

**84-2066**

**Diffraction of Torsional Wave by a Circular Rigid Disc at the Interface of Two Bonded Dissimilar Elastic Solids**

B.M. Singh, J. Rokne, and R.S. Shaliwal

Univ. of Calgary, Calgary, Alberta, Canada, Acta Mech., 49 (1, 2), pp 139-149 (1983) 2 figs, 10 refs

Key Words: Seismic waves, Wave diffraction, Disks

The problem of diffraction of normally incident SH waves by a circular rigid disc situated at the interface of two elastic dissimilar elastic half-spaces is considered. The problem is reduced to the solution of dual integral equations. Approximate solution of dual integral equations is obtained by reducing the problem to the solution of Fredholm integral equations of the second kind. The solution is used to calculate dynamic stress intensity factor. Numerical values of stress intensity factor versus wave number are graphed.

# EXPERIMENTATION

## MEASUREMENT AND ANALYSIS

(Also see Nos. 1975, 2011)

**84-2067**
**Dual Channel FFT Analysis (Part 1)**
H. Herlufsen
Tech. Rev (B & K), (1), (1984) 34 figs, 1 table, 11 refs

Key Words: Fast Fourier transform, Cross spectral method, Coherence function technique

Basic dual channel FFT measurements are introduced. The physical interpretation of the cross spectrum, which is the fundamental function in these measurements, and the coherence function are dealt with in some detail Two different methods for estimating the complex frequency response function of a system, from the input and the output signals, are derived, and it is shown which of the two estimates should be used in different practical measurement situations. Various excitation techniques for system analysis are described and their advantages and disadvantages for specific applications outlined.

**84-2068**
**Multishaker Modal Testing**
R R. Craig, Jr.
Univ. of Texas at Austin, Rept. No. CAR-83-2, NASA-CR-170952 35 pp (Oct 1983)
N84-15521

Key Words: Modal tests, Modal models, Multipoint excitation technique

Procedures for improving the modal modeling of structures using test data and to determine appropriate analytical models based on substructure experimental data were explored. Two related research topics were considered in modal modeling: using several independently acquired columns of frequency response data, and modal modeling using simultaneous multipoint excitation. In component mode synthesis modeling the emphasis is on determining the best way to employ complex modes and residuals.

**84-2069**
**Multishaker Broadband Excitation for Experimental Modal Analysis**
D.L. Hunt and E.L. Peterson
SDRC, Inc., San Diego, CA, SAE Paper No. 831435

Key Words: Experimental modal analysis, Modal analysis, Multiple sine dwell method, Single point excitation technique

A new method of excitation for modal testing is described which combines the benefits of the two most often used techniques: multipoint sine dwell and single-point random. This new method -- multishaker broadband excitation -- employs an array of shakers to develop multiple sets of frequency response functions, which, as evidenced by their reciprocity and consistency, yield a more accurate representation of the structure's dynamics, resulting in a better modal model. Additionally, this new technology offers a significant reduction in time required to perform a modal survey.

**84-2070**
**Innovative Functions for Two-Channel FFT Analyzers**
R. Upon
Bruel & Kjaer, Denmark, S/V, Sound Vib., 18 (3), pp 18, 19, 22-25 (Mar 1984) 11 figs, 6 refs

Key Words: Frequency analyzers, Fast Fourier transform, Frequency response function

This article discusses the background of two extra functions which can now be obtained from 2-channel FFT analyzers. The first of these, $H_2$, is a new means of measuring a frequency response function. It is shown that situations exist where $H_2$ can offer distinct advantages over the traditional method of measurement, $H_1$. The second is the Hilbert transform, which can be a considerable aid in the interpretation of correlation functions and impulse response. Use of $H_2$ and the Hilbert transform is illustrated with results from some practical measurements.

**84-2071**
**The Vibrometer -- A Draft Load Vibrating Reed Sensor**
N.M. Stefano
TRW Transportation Electrical and Electronics Operations, SAE Paper No. 831319

Key Words: Vibration meters, Measuring instruments, Vibration measurement

A small strip of spring steel is integrally mounted in a counterbored hole in a draft bar so that a tension or compression load on the bar will change the length and load on the strip, changing its natural frequency. A magnetic circuit is used to disturb the strip, to keep it vibrating, and sense the vibration frequency. The design parameters are explored, and laboratory and field test data are presented.

**84-2072**

**Frequencies of Piezoelectrically Forced Vibrations of Electroded, Doubly Rotated, Quartz Plates**

R.D. Mindlin

P.O. Box 385, Grantham, NY 03753, Intl. J. Solids Struc. 20 (2), pp 141-157 (1984) 5 figs, 8 refs

Key Words: Plates, Piezoelectricity, Equations of motion

Two-dimensional equations of motion of piezoelectric crystal plates, obtained from the three-dimensional equations of linear piezoelectricity by expansion in power series of the thickness coordinate of the plate, are solved for forced vibrations of electroded SC-cut quartz plates. Results of computations are given for frequencies of simple thickness modes of vibration, for the dispersion of straight-crested waves and for frequencies of vibration of a strip, along with its dimensional ratios for minimal coupling of the fundamental thickness-shear mode with overtones of flexure, face-shear and thickness-twist.

**84-2073**

**Determining and Modelling the Response of Piezoresistance Transducers to Dynamic Loading**

Y.M. Gupta

Dept of Physics, Washington State Univ., Pullman, WA Rept. No. AFOSR-TR-83-1286, 8 pp (June 1983)

AD-A137 121

Key Words: Transducers

The work of the past year has concentrated on experimental measurements and their analyses. The response of Ytterbium (Yb) foils, oriented parallel and perpendicular to the shock front, was obtained for well defined loading and unloading. The foils were embedded in a PMMA matrix and the longitudinal stress ranged between 0.1 and 2.0 GPa. Results have provided an empirical calibration for Yb under shock wave uniaxial strain loading. An important result from these experiments is the verification of an elastic-plastic inclusion analysis.

**84-2074**

**Systems Approach to Measuring Short Duration Acceleration Transients**

F. Schelby

*Sandia National Labs., Albuquerque, NM*, 29 pp (June 1983) (Transducer Workshop (12th) held at Melbourne, FL, June 7-9, 1983, pp 476-504)

AD-P002 690

Key Words: Accelerometers

It is common for failures to occur when attempting to acquire acceleration structural response measurements during crash, impact, and pyrotechnic testing. The structural response of a mechanical system to severe transient loading is commonly measured by accelerometers which are less than ideal. In particular, their amplitude-frequency response has one or more resonant peaks so that the output of the accelerometer may not be an exact replica of the input. If the transient input stimulus contains frequencies near these resonant peaks, signal distortion, over-ranging of signal conditioning electronics, or even failure of the sensing element may occur. These and other problems have spurred the development of a new acceleration-measuring system which incorporates the following features: transduction element, connectors, mounting, electronics, and transducer resonance.

**84-2075**

**Calibration of Vibration Pickups at High Frequencies**

B.F. Payne

National Bureau of Standards, Washington, DC, 11 pp (June 1983) (Transducer Workshop (12th) held at Melbourne, FL, June 7-9, 1983, pp 505-515)

AD-P002 691

Key Words: Accelerometers, Calibrating

Improved design of vibration pickups by several accelerometer manufacturers has resulted in low-mass or miniature accelerometers with extended frequency response. This paper discusses methods for measuring the frequency response (calibration) of this type of miniature accelerometer. By using a calibration system composed of a Michelson interferometer with a helium-neon laser as a light source, absolute displacement measurements can be obtained over the frequency range of approximately 2 to 30 kHz. Using techniques developed at NBS, measurements can be obtained at amplitudes of 121 nm and 193 nm. Since the vibration exciters have limitations in amplitude, the 121-nm technique enables higher frequency measurement capability. These measurement techniques and the experimental measurement apparatus are discussed in this paper.

**84-2076**

**Testing Techniques Involved with the Development of High Shock Acceleration Sensors**

R.D. Sill

Endevco Corp., San Juan Capistrano, CA, 18 pp (June 1983) (Transducer Workshop (12th) held at Melbourne, FL, June 7-9, 1983, pp 534-551)

AD-P002 693

Key Words: Testing techniques, Accelerometers

This paper describes testing techniques and equipment used in the development of a shock accelerometer, having a range beyond 100 000 g and a mounted resonant frequency on the order of a megahertz. Conventional testing techniques proved inadequate for thorough evaluation. A new calibration system based on the Hopkinson bar has been developed to give rigorous and accurate tests to determine sensitivity, amplitude linearity and zero shift due to accelerations beyond the transducer's designed full scale acceleration level. A related but smaller apparatus was developed to determine resonant frequency and also, although to a very rough degree, the frequency response of the accelerometer. It provided the means to create sub-microsecond rise time strain waves to excite an accelerometer's resonant frequency.

**84-2077**

**Measuring and Automated Processing of the Frequency Response Functions of Dynamical Systems with Regard to Accuracy of Determination of the Phase Frequency Response**

R. Chmúrny and P. Tirinda

Inst. of Materials and Machine Mechanics of the Slovak Academy of Sciences, Bratislava Czechoslovakia, *Strojnicky Casopis*, 35 (1-2), pp 67-76 (1984) 3 figs, 5 refs

(In Slovak)

Key Words: Measurement techniques, Frequency response function

An efficient method for measuring the frequency response functions of vibrating systems is described. The prerequisite of this method is a mincomputer equipped with an appropriate laboratory peripheral system for analogue data acquisition, directly connected to the experiment.

**84-2078**

**Hydroacoustic Impedance Measurement of Large-Area Samples in the Frequency Range $u_{\rho}$ to 200 kHz**

D. Guicking and K. Karcher

Drittes Physikalisches Institut, Univ. of Göttingen, Burgestr. 42-44, D-3400 Göttingen, Fed. Rep. Germany, Acustica, 54 (4), pp 200-208 (Feb 1984) 18 figs, 7 refs

Key Words: Measuring instruments, Underwater sound, Acoustic impedance

A wide-tube device is described permitting the complex acoustic impedance of large-area samples to be measured in water in the frequency range from about 30 kHz to 200 kHz. The diameters of two tubes employed (29 cm and 12.5 cm) are large as compared to the acoustic wavelengths in water. The system works with plane sound waves generated by a point source in the focus of a parabolic reflector. Measurements are performed by the pulse-echo method and comparison with a resilient reference reflector.

**84-2079**

**The Determination of Elastic Constants of Isotropic Tube-Shaped Samples from Ultrasonic Vibrations**

Th. Frechen and G. Dietz

II Physikalisches Institut der Universitat zu Koln, Zulpicher Strasse 77, D 5000 Koln 41, Fed. Rep. Germany, J. Phys. E: Sci. Instrum., 17 (3), pp 208-211 (Mar 1984) 4 figs, 6 refs

Key Words: Ultrasonic vibration, Measurement techniques

A method of simultaneous measurement of both elastic constants of tube-shaped isotropic ferromagnetic metals is presented. It can be extended to nonmagnetic material. The experimental device operates at ultrasonic frequencies and provides a fast and easy change between torsional and extensional modes. Inexpensive equipment is used to measure the ultrasound velocities to good accuracy by a high-order standing-wave method. The mechanism of magnetostrictive generation of torsional and extensional vibrations and the procedure of evaluating the elastic constants are described.

**84-2080**

**Torsional Vibration Measurement and Analysis: A New Technique**

M.S. Henry

Schwitzer Pumps & Dampers, SAE Paper No. 831320

Key Words: Torsional vibrations, Vibration measurement, Measurement techniques

The need for an accurate, reliable and durable torsional vibration measurement system that could be used for the evaluation of any engine application is essential. The measurement system has two basic components, an engine mounted transducer and signal conditioning/data reduction equipment. The transducer must be selected before other system components can be identified or developed. A prototype transducer has been evaluated and proven to meet the above criteria. Its performance has been verified with the use of redundant test methods. This instrumentation included proximity probes, linear accelerometers, an angular velocity transducer and optical methods.

**84-2081**

**Problems and Solutions in Impulse Noise Dosimetry**

J. Erdreich

National Inst for Occupational Safety and Health, Cincinnati, OH, S/V, Sound Vib., 18 (3), pp 28-32 (Mar 1984) 5 figs, 2 tables 11 refs

Key Words: Noise measurement, Measuring instruments

There are two related problems with impulse noise dosimetry. The first is the uncertainty of dose/response relationships for impulsive exposure. The second is the problem of acceptable instrumentation for the impulsive environment. By reconsidering the evolution of dosimeter design and the purpose to which it must now be applied the problem of instrumentation can be resolved. Only after this, will it then be appropriate to address development of a scientifically sound dose/response relationship. In the interim, solutions which will provide a workable measurement are considered.

**84-2082**

**A Method for Measurement of Dynamic Torque (Messverfahren zur dynamischen Drehmomentbestimmung)**

G Gurich, U. Milz, and H.-C. Wolf

Lehrstuhl f. Messtechnik, RWTH, Aachen, Templergraben 55, D-5100 Aachen, Techn. Messen-TM, 51 (3), pp 105-110 (1984) 8 figs 13 refs

Key Words: Measurement techniques, Torque

An accurate determination of dynamic torque from the measurement under static conditions is obtained by adding the torque of d'Alembert's force of inertia (the difference between the inertia moment and angular acceleration) to the exciting moments. The applicability of this method is illustrated in the measurement of internal torque of three phase induction machines.

**84-2083**

**The Design of Low Frequency Chambers Using Computer Simulation Techniques with Emphasis on Automotive Chambers**

J.C. Hungerford

Emerson & Cuming, Canton, MA, SAE Paper No. 831014

Key Words: Anechoic chambers, Computer-aided techniques

Three dimensional plots of the frequency and spatial behavior of the transfer function of a reflecting floor anechoic chamber are presented to illustrate the chamber properties. Chamber measurement techniques and the information contained within the data are discussed.

## DYNAMIC TESTS

**84-2084**

**The Impedance Method of Non-Destructive Inspection**

P. Cawley

Imperial College of Science and Tech., Exhibition Rd. London SW7 2BX, UK, NDT Intl., 17 (2), pp 59-65 (Apr 1984) 11 figs, 1 table, 11 refs

Key Words: Nondestructive tests, Impedance technique

The physical basis of the impedance method of non-destructive testing is investigated. A theoretical study is backed up by impedance measurements on structures with deliberately introduced disbonds. It is shown that defects such as disbonds and delaminations may be modeled as a spring beneath which is the undamaged structure, the spring stiffness being infinite if no defect is present. The impedance at the top of the spring is a strong function of the spring stiffness, so impedance measurements may be used to detect damage. The technique is most sensitive when the defect is close to the surface and the base structure is relatively stiff.

**84-2085**

**The Measurement of Impact Forces under Dynamic Crush Using a Drop Tower Test Facility**

C.C. Chou

Ford Motor Co., SAE Paper No. 830467

Key Words: Test facilities, Dynamic tests, Compressive strength

This report describes an experimental method for determining the force-deflection characteristics during dynamic crush of square steel columns using a drop tower test facility. The custom-designed load cells were used for the measurements of the impact and the reaction forces at both ends of specimens, which were subjected to a 30 mph impact. Instrumentation for data acquisition and detailed data reduction for analysis are also presented. Dynamic force-deflection data are then verified through energy computations of the total kinetic energy of the system and the resulting energy absorbed by the specimens, which are calculated from measured impact forces and dynamic deflection.

**84-2086**

**HDR (Heissdampfreaktor) Flood-Water Storage-Tank Modal Vibration Tests**

V.W Gorman and G.L. Thinnes

EG and G Idaho, Inc., Idaho Falls, Rept. No. EGG-M-16282, CONF-830805-55, 17 pp (1983) (Intl. Conf. on Struc. Mech. in Reactor Tech., Chicago, IL, Aug 22, 1983)

DE84001002

Key Words: Nuclear reactors, Modal tests

Modal vibration tests were conducted on two vessels located at West Germany's Heissdampfreaktor (HDR) facility. The primary purpose for performing these tests was to determine modal properties (frequencies, mode shapes and associated damping ratios) in order to eventually provide guidelines for standards development in modeling similar vessels. Excitation or input forces together with measured vessel responses were processed by a digital modal analyzer and stored on magnetic disks for subsequent evaluation.

**84-2087**

**Aircraft Ground Vibration Test Instrumentation System**

R. Talmadge and D. Banaszak

Air Force Wright Aeronautical Labs , Wright-Patterson AFB, OH, 28 pp (June 1983) (Transducer Workshop (12th) held at Melbourne, FL, June 7-9, 1983, pp 552-579)

AD-P002 694

Key Words: Test facilities, Vibration tests, Aircraft

An in-house ground vibration test (GVT) on a full scale F-16 aircraft located inside a vibration aeroelastic facility was conducted. To measure 120 accelerometer signals simultaneously as required by the GVT, a complete data acquisition system to measure and condition all the required transducer signals was designed and fabricated in-house. This paper describes the design, configuration, evaluation and calibration of the GVT instrumentation system.

**84-2088**

**Effect of Measurement System Phase Response on Shock Spectrum Computation**

P.L. Walter

Sandia National Labs., Albuquerque, NM, 17 pp (June 1983) (Transducer Workshop (12th) held at Melbourne, FL, June 7-9, 1983, pp 360-396)

AD-P002 688

Key Words: Shock tests, Spacecraft components, Phase effects

One of the standard methods for characterizing mechanical shock is by means of the shock spectrum. The principal application of the shock spectrum in aerospace technology is to permit component shock test specifications to be generated, independent of specific time histories. Inattention to the dynamics of the instrumentation system used to measure mechanical shock can result in distorted test data. Erroneous component test specifications will originate from shock spectra calculations based on these distorted data. This documents' premise is that measurement system design is frequently based upon amplitude response considerations with phase response ignored. In structural testing nonlinear phase response in measurement systems results in distorted transient data being recorded for analysis with resultant error in the computed shock spectra. Design guidelines are provided in this work to preclude these errors from occurring.

## SCALING AND MODELING

**84-2089**

**Model Law for Concrete Structures under Dynamic Loads**

H.R. Fuehrer

Martin Marietta Orlando Aerospace, Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 2, pp 97-102, 1 table, 10 refs

Key Words: Scaling, Concrete, Reinforced concrete

Most physical systems can be studied by means of scale models whose behavior relates in a known way to that of a prototype. The problem is to write a valid scaling law that accurately displays this similarity. This requires a certain familiarity with the physical concepts involved in the system. Certain laws of similitude must be observed to ensure that model test data can be applied to the prototype. Insight and rationale for use in defining a scaling law for reinforced concrete under dynamic loads are provided.

## DIAGNOSTICS

**84-2090**

**New Monitors Expand Benefits of Machine-Condition Surveys**

J. Makansi Assoc. Editor

Power, 128 (5), pp 75-76 (May 1984) 1 fig

Key Words: Diagnostic techniques, Diagnostic instrumentation

An introduction to cost-effective predictive maintenance of noncritical rotating equipment is presented. This is achieved by hand-held instruments which measure and store machinery-health data for later trending and analysis in a computer -- simplifying and reducing the cost of data collection and reduction.

**84-2091**

**Machine Diagnosis for a Complete Utilization of Wear Reserves and for the Increase of Reliability -- A New Diagnostic Procedure (Maschinendiagnose zuer Ausschöpfung von Abnutzungsreserven und zur Erhöhung der Zuverlässigkeit - Ein neues Diagnoseverfahren)**

A. Sturm, D. Kinsky R. Forster and M. Bode

Ingenieurehochschule Zittau, German Dem. Rep., Maschinenbautechnik, 33 (3), pp 100-105 (Mar 1984) 11 figs, 3 tables, 6 refs

(In German)

Key Words: Diagnostic techniques, Rolling contact bearings, Bearings

After numerous systematic experimental investigations of the failure process of rolling element bearing machinery and relevant diagnostic parameters, as well as a theoretical evaluation of the results, a new more reliable diagnostic technique was developed. The new diagnostic parameter takes the effective value, the original condition and the time point of diagnosis into consideration. The algorithm is solved on a portable diagnostic instrument. The instrument is simple to operate and user friendly.

**84-2092**

**Application of X-Ray Measurement to Bearing Failure Analysis**

*H. Nakashima, K. Maeda, N. Tsushima, and H.Muro*

NTN Toyo Bearing Co., Ltd., SAE Paper No. 830825

Key Words: Diagnostic techniques, Failure analysis, X-ray techniques, Bearings

X-ray measurement is a very useful tool for bearing failure analysis. Compressive residual stress is created under the bearing raceway if bearings are used under a contact stress higher than the critical value. Residual stress distribution measurement of a used bearing enables to presume contact stress in service. Half height breadth of diffracted X-ray also changes with the fatigue of the material. Therefore X-ray measurement may estimate the degree of fatigue of a used bearing. Fracture surface of a fractured bearing has sometimes a high tensile residual stress at the surface, from which we can presume the fracture toughness of the material and then calculate the fracture stress.

**84-2093**

**Noise Analysis for Gear Box Defect Detection**

K. Bagiasna, H. Suganda, and D. Suharto

SAE Paper No. 830924 (P-139)

Key Words: Diagnostic techniques, Gear boxes

Transmission gear boxes of small size transportation vehicles are investigated using noise analysis based on Campbell as well as Order ratio diagram. The emitted noise signal is analyzed digitally using a spectrum analyzer and computerized data processing is performed to identify noise sources of the rotating elements.

**84-2094**

**Acoustic Emission for On-Line Reactor Monitoring: Results of Intermediate Vessel Test Monitoring and Reactor Hot Functional Testing**

P.H. Hutton and R.J. Kurtz

Battelle Pacific Northwest Labs., Richland, WA, Rept. No. PNL-SA-11634, CONF-8310143-61, 20 pp (Oct 1983) (NRC Water Reactor Safety Research Information Mtg., Gaithersburg, MD, Oct 14, 1983) DE84003259

Key Words: Acoustic emission, Failure detection, Nuclear reactors, Pressure vessels, Piping systems

The objective of the acoustic emission (AE)/flaw characterization program is to provide an experimental feasibility evaluation of using the AE method on a continuous basis (during operation and during hydrotest) to detect and analyze flaw growth in reactor pressure vessels and primary piping. This effort is based on earlier results showing that AE has potential for being a valuable addition to nondestructive evaluation (NDE) methods with the added unique capability for continuous monitoring, high sensitivity and remote flaw location. Results are reported for the ZB-1 vessel test and the Watts Bar-1 hot functional test.

**84-2095**
**Investigations of the Mechanical Behavior of Spot Welded Joints by Means of Acoustic Emission Analysis**
H.A. Crostack
Lawrence Livermore National Lab., CA, Rept. No. UCRL-Trans-11916, 193 pp (Nov 5, 1983) DE84003041

Key Words: Failure detection, Acoustic emission, Joints (junctions), Welded joints

The investigations carried out on the mechanical behavior of spot-welded joints give information about the separate stages of the failure and determine the magnitude of the influencing parameters. In this way the strength of the joints can be raised. In addition to the acoustic emission analysis and metallographic and electron-optical investigations to establish the crack development, interpretation is also based on fracture mechanics and the variations in the internal stresses. With the aid of these procedures, it proved possible to construct a model which is able to explain the various failure patterns of a spot-welded joint under shear-tension loading.

## BALANCING

**84-2096**
**Internationally Discussed Problems in Balancing Rotors**
K. Federn
Technische Universität Berlin, Berlin, W. Germany, Intl. Fed. of Theory of Machines and Mechanisms, 6th Congress, Tech. Committee on Rotordynamics Session Proc., Indian Inst. of Tech., New Delhi, India, Dec 19, 1983, pp 30-34, 22 refs

Key Words: Rotors, Balancing techniques

The rapidly proceeding development of the rotor balancing technique and its records in the abundant literature were promoted by international standardization, by computer hardware and software, and by early introduction of microelectronics into data processing -- from the electrical information about unbalance-induced vibrations up to the display of unbalances. The economically and technically optimized balancing of rigid rotors in large-scale series production, but also the high-speed balancing of flexible rotors in the course of production and in situ, even with multiple-bearing support, cause no problems, for which suitable special-purpose machines, general-purpose machines, instrumentation and programs are not at disposal in sufficient variety.

## MONITORING

**84-2097**
**The Dynamical Behavior of Cracked Rotors**
O. Mahrenholtz
Technische Universitat Hamburg-Harburg, Fed. Rep. Germany, Intl. Fed. of Theory of Machines and Mechanisms, 6th Congress, Tech. Committee on Rotordynamics Session Proc., Indian Inst. of Tech., New Delhi, India, Dec 19, 1983, pp 35-40, 4 figs, 42 refs

Key Words: Monitoring techniques, Crack detection, Failure detection, Rotors

Propagating cracks in rotating shafts have in several cases caused severe damage to turbomachinery. It is therefore necessary for engineers to develop tools for crack detection. The progress in monitoring systems is well-known and in many countries the task of modeling the dynamical behavior of cracked rotors, using modern computation techniques, is being challenged. A future task will be to combine the theoretical knowledge with the monitoring possibilities.

**84-2098**
**Vibration Monitoring of Rolling Element Bearings by the High-Frequency Resonance Technique -- A Review**
P.D. McFadden and J.D. Smith

Engrg. Dept., Cambridge Univ., Trumpington St., Cambridge CB2 1PZ, UK, Trib. Intl., 17 (1), pp 3-10 (Feb 1984) 10 figs, 19 refs

Key Words: Monitoring techniques, Bearings, Rolling contact bearings, High frequency resonance technique

Vibration monitoring of rolling element bearings by the high-frequency resonance technique is reviewed. It is shown that the procedures for obtaining the spectrum of the envelope signal are well established, but that there is an incomplete understanding of the factors which control the appearance of this spectrum. Until the envelope spectrum can be fully explained, use of the technique is limited

**84-2099**

**Damage Detection in Offshore Structures by the Random Decrement Technique**

J C.S. Yang, J. Chen, and N.G. Dagalakis

Univ. of Maryland, College Park, MD 20742, J. Energy Resources Tech., Trans. ASME, 106 (1), pp 38-42 (Mar 1984) 8 figs, 1 table, 10 refs

Key Words: Off-shore structures, Drilling platforms, Failure detection, Damage prediction, Random decrement technique

The random decrement technique has shown promise as an inspection technique for offshore structures. The major advantage of this technique is that it requires only measurements of the dynamic response of the structure and not the input excitation causing the response. On offshore platforms, such random input forces occur from wind, waves, and currents The random decrement technique is evaluated together with a number of other techniques.

# ANALYSIS AND DESIGN

## ANALYTICAL METHODS

**84-2100**

**Performing Dynamic Time History Analyses by Extension of the Response Spectrum Method**

G.M. Hulbert

Advanced Reactors Div., Westinghouse Electric Corp., Madison, PA, Rept. No. CONF-830607-28, 13 pp (1983) (ASME Pressure Vessel and Piping Conf., Portland, OR, June 19, 1983)
DE84001852

Key Words: Response spectra, Seismic design, Piping systems

A method is presented to calculate the dynamic time history response of finite-element models using results from response spectrum analyses. The proposed modified time history method does not represent a new mathematical approach to dynamic analysis but suggests a more efficient ordering of the analytical equations and procedures. The modified time history method is considerably faster and less expensive to use than normal time history methods. This paper presents the theory and implementation of the modified time history approach along with comparisons of the modified and normal time history methods for a prototypic seismic piping design problem.

**84-2101**

**Finite Element Modeling of Soil-Machine Problems**

J.V. Perumpral and T. Kuppusamy

Virginia Polytechnic Inst., Blacksburg, VA, SAE Paper No. 830806

Key Words: Interaction: soil-machine, Finite element technique

A brief description of the finite element formulation and its advantages are discussed. A review of past studies dealing with finite element application to soil-machine interaction problems and suggestions for future research are also included.

**84-2102**

**An Improved Method of Dynamic Coupling in Structural Analysis and Its Applications**

T. Inamura, H. Suzuki, and T. Sata

Kanazawa Univ. 2-40-20, Kodatsuno, Kanazawa 920, Japan, J. Dynam. Syst , Meas. Control, Trans. ASME, 106 (1), pp 82-89 (Mar 1984) 10 figs, 15 refs

Key Words: Dynamic structural analysis, Design techniques

An improved method of dynamic coupling is developed for use in an interactive structural analysis system. The method is used to couple the values ‹ t the lowest few modes of the dynamic characteristics of structures at a high speed. Additional techniques are proposed to confine computation to those points necessary for evaluation and to couple the values under the condition that the nodal points to be connected have different coordinates from each other. Some examples of the analyses are illustrated to show the efficiency of the proposed methods.

**84-2103**

**Index Evaluation for Dynamical Systems and Its Application for Locating All the Zeros of a Vector Function**

C.S. Hsu and R.S. Guttalu

Univ. of California, Berkeley, CA, ASME Paper No. 83-WA/APM-19

Key Words: Point mapping method

An index evaluation method is discussed It can also serve as the basis of a procedure to locate all the zeros of a vector function. An application of the procedure is made to a strongly nonlinear point-mapping dynamical system in order to locate all the periodic solutions of period one and period two 41 in total number

**84-2104**

**Finite Element Analysis of Dynamic Coupled Thermoelasticity Problems with Relaxation Times**

J.H. Prevost and D. Tao

Princeton Univ., Princeton, NJ ASME Paper No. 83-WA/APM-9

Key Words: Finite element technique, Thermoelasticity

A general finite element model is proposed to analyze transient phenomena in thermoelastic solids. Green and Lindsay's dynamic thermoelasticity model is selected for that purpose since it allows for second sound effects and reduces to the classical model by appropriate choice of the parameters. The procedure proves to be most effective and versatile in thermal and stress wave propagation analysis.

**84-2105**

**Incremental Harmonic Balance Method with Multiple Time Scales for Aperiodic Vibration of Nonlinear Systems**

S.L. Lau, Y.K. Cheung, and S.Y. Wu

Hong Kong Polytechnic, ASME Paper No. 83-WA/APM-7

Key Words: Harmonic balance method, Periodic response

An incremental harmonic balance method with multiple time scales is presented. As a general and systematic computer method, it is capable of treating aperiodic steady-state vibrations such as combination resonance, etc. Moreover, this method is not subjected to the limitation of weak nonlinearity.

**84-2106**

**The Development of Finite Element Modeling and Experimental Techniques for Dynamic Analysis of Read/Write Head Designs on Floppy Disk Media**

J.K. Good

Ph.D. Thesis, Oklahoma Statate Univ., 141 pp (1983) DA8402615

Key Words: Computer systems hardware, Vibration analysis, Finite element technique

The finite element method is used to study vibration characteristics of both gimbaled and non-gimbaled read/write heads. Both eigenvalue and transient analyses are performed. An experimental apparatus is developed which can sense the three major displacement components versus time. Experimental data thereof is correlated to results from the finite element study.

## MODELING TECHNIQUES

**84-2107**

**Modelling of Stable Nonstationary Dynamic Random Processes with a Nonstationary Autocorrelation**

J. Čačko

Inst. of Materials and Machine Mechanics of the Slovak Academy of Sciences, Bratislava, Czechoslovakia, Strojnícky Časopis, 35 (1-2), pp 39-49 (1984) 4 figs, 3 refs

(In Slovak)

Key Words: Autocorrelation technique, Mathematical models

A method enabling the modeling of nonstationary random processes with stationary standard autocorrelation which was extended in a previous paper for the event of a part by part stationary standard autocorrelation function is further extended for the event of a nonstationary standard autocorrelation, presupposing the stability of a modeled process.

**84-2108**

**Theoretical and Software Considerations for Nonlinear Dynamic Analysis**

R.J. Schmidt and R.H. Dodds Jr.

Univ. of Kansas, Lawrence, KS, Rept. No. SM-8, NASA-CR-174504, 299 pp (Feb 1983)

N84-15589

Key Words: Substructuring methods Computer programs, Nonlinear theories

In the finite element method for structural analysis, it is generally necessary to discretize the structural model into a very large number of elements to accurately evaluate displacements, strains, and stresses. As the complexity of the model increases, the number of degrees of freedom can easily exceed the capacity of present-day software system. Improvements of structural analysis software including more efficient use of existing hardware and improved structural modeling techniques are discussed. One modeling technique that is used successfully in static linear and nonlinear analysis is multilevel substructuring. This research extends the use of multilevel substructure modeling to include dynamic analysis and defines the requirements for a general purpose software system capable of efficient nonlinear dynamic analysis. The multilevel substructuring technique is presented, the analytical formulations and computational procedures for dynamic analysis and nonlinear mechanics are reviewed, and an approach to the design and implementation of a general purpose structural software system is presented.

## DESIGN TECHNIQUES

**84-2109**

**The Role of Static and Dynamic Finite Element Analysis in Designing Low-Noise Cylinder Blocks**

Y. Usuba, I. Nagayama, Y. Araki, and K. Kakuta

Nissan Motor Co., Ltd., Yokohama, Japan, SAE Paper No. 830251

Key Words: Engine cylinder blocks, Noise reduction Design techniques, Finite element technique

The finite element method is now being used for designing low-noise cylinder blocks. Either static or dynamic analysis is generally used to determine the block structure. However, investigation of the cylinder block behavior of a running engine shows that the vibration consists of two phenomena, which are the initial elastic deformation and the natural vibration. Therefore, it is necessary to study both phenomena by using simulation techniques in order to determine the optimum design of a low-noise cylinder block, taking into consideration its weight. In this study, static and dynamic finite element analyses were applied to simulate each phenomenon, and the relationship between the static and dynamic response and the components of the cylinder block was examined.

## COMPUTER PROGRAMS

**84-2110**

**IMPAC2; Edition B; Shipping Container Impact Analysis**

J.B. Payne and J. Counts

Los Alamos National Lab., NM, Mag tape ANL/NESC-715 (1984)

DE83048715

Key Words: Computer programs, Impact response, Shipping containers

IMPAC2 solves the equations of motion for a one-dimensional, lumped-mass, nonlinear spring mathematical container model. The program was designed to analyze the dynamic response of metallic shipping containers impacting an unyielding surface. The container may consist of several hollow concentric cylinders, each of a different material and length.

**84-2111**

**SAP4; Structural Analysis of Linear Systems**

S. Zawadzki, S. Gledhill, and B. Davis

Argonne National Lab., IL, Mag Tape ANL/NESC-641 (1984)

DE83048641

Key Words: Computer programs, Structural members

SAP4 is a structural analysis program for determining the static and dynamic response of linear systems. The structural systems to be analyzed may be composed of combinations of a number of different structural elements. Presently, the program contains the following element types: three-dimensional truss element, three-dimensional beam element, plane stress and plane strain element, two-dimensional axisymmetric solid, three-dimensional solid, variable-number nodes thick shell and three-dimensional element, thin-plate or thin-shell element, boundary element, and pipe element (tangent and bend).

# GENERAL TOPICS

## CRITERIA, STANDARDS, AND SPECIFICATIONS

**84-2112**

**The Use of Compendia, Design Manuals, and Reference Texts in Prediction of Nonnuclear Weapons Effects**

W.E. Baker

Southwest Res. Inst., Interaction of Non-Nuclear Munitions with Structures, Proc. Symp. U.S. Air Force Acad., CO, May 10-13, 1983, Vol. 1, pp 124-129, 27 refs

Key Words: Weapons effects, Manuals and handbooks

The literature on nonnuclear weapons effects dates from the 16th century, is extensive, is widely scattered, and includes many classified references. This diffusion presents problems to both neophytes and experts in this field -- the neophyte can be overwhelmed by the volume of the literature, and unable to choose between conflicting references or prediction methods; while the expert may be expert in only a narrow specialty in weapons effects, and not truly conversant with other specialties. So, a limited library of broad references on the symposium topic can be very useful. The paper discusses the coverage of each cited general reference notes the depth or lack of depth of literature reference, and gives a brief evaluation of the reference.

**84-2113**

**Child Restraints Legislation in Europe**

J.C. Bastiaanse and J. Maltha

Res. Inst for Road Vehicles TNO, Delft, The Netherlands, SAE Paper No. 831651 (P-135)

Key Words: Safety restraint systems, Standards and codes

A short review is presented on crash protection standards for children in European countries. An evaluation of the crash performance of a wide variety of current restraint systems is presented, based on two years of experience with the new ECE 44 regulation on child restraints. This shows the restrictive nature of the regulation and the need for substantial redesign of most of the current products.

**84-2114**

**Compliance Testing to the New Dynamic Standard for Child Restraint Systems**

J.C. Gilkey

Dept. of Transportation, National Highway Traffic Safety Admn., SAE Paper No. 831660 (P-135)

Key Words: Collision research (automotive), Safety restraint systems, Standards and codes

A new dynamic performance standard for child restraint systems became effective on January 1, 1981. A test procedure and conducted compliance tests to determine whether the systems available in the marketplace met the requirements of the standard was developed. The restraints tested were in compliance with the dynamic systems test requirement of the standard, however, some of the systems failed to meet certain component test requirements. Technical investigations were initiated to examine more fully the extent of the apparent noncompliances to the standard.

**84-2115**

**Development of a Seat Belt Booster Cushion Standard**

P.E. Waters

Dept. of Transport, England, SAE Paper No. 831653 (P-135)

Key Words: Safety restraint systems, Seat belts, Standards and codes

With a desire to devise some means of child restraint that would find wider acceptance and use than the traditional child restraint, it was decided to develop a standard for seat belt booster cushions. These are a firm seat for a child designed to improve the fit of an adult seat belt and which can readily be removed and used in any car in which the child might be required to travel.

**84-2116**

**Development of Infant and Child Restraint Regulations and Their Application**

V.G. Radovich

Office of Vehicle Safety Standards, National Highway Traffic Safety Admn., SAE Paper No. 831655 (P-135)

Key Words: Collision research (automotive), Safety restraint systems, Regulations

An overview of the evolution of child restraints and related safety standards in the U.S.A. is given. Some current and planned work pertaining to installation of child restraint and evaluation of restraints for use by older children is also described. The main provisions of four standards are reviewed and comparison of their major provisions is made.

**84-2117**

**The State of the Art of Child Passenger Safety Legislation in North America**

E.W. Lawless and T.A Siani

National Child Passenger Safety Assn., SAE Paper No. 831650 (P-135)

Key Words: Safety restraint systems, Regulations

Child safety seats provide an effective means for protecting children in car crashes. Forty states, the District of Columbia, and five Canadian provinces have now passed child passenger safety laws. These laws vary considerably from state to state. The most important provisions and variations among these laws are summarized.

## USEFUL APPLICATIONS

**84-2118**

**Nonintrusive Acoustic System for the Dynamic Timing of Diesel Engines**

R.C. Davis, D.L. Hagen, H.C. Scherrer, D.B. Kittelson, E.D. Lowell, and A.G. Tidball

Univ. of Minnesota, Minneapolis MN, SAE Paper No. 830102

Key Words: Vibratory techniques, Timing devices, Diesel engines

Vibration signals from diesel engines were analyzed for the purpose of isolating signals relating to injection or combustion which could be used to time the engines. Nonintrusive sensors, magnetically attached to the engine, were used to obtain these vibration signals. Components believed to be associated with combustion or fuel injection were electronically isolated from the remaining engine noise, and subsequently processed to produce specific timing signals. Digital data acquisition and averaging methods were used, coupled with computerized frequency analysis.

**84-2119**

**Vibrations Increase Available Power at the Bit**

D.W. Dareing

Christensen, Inc., Houston, TX, ASME Paper No. 84-Pet-10

Key Words: Rock drills, Vibratory tools

Dynamic forces applied to roller cone rock bits have the potential to increase penetration. This paper quantifies the available vibration energy at the bit and shows how to control the level of energy through bottom hole assembly design and rotary speed.

# AUTHOR INDEX

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# CALENDAR

## OCTOBER 1984

1-3 Army Symposium on Solid Mechanics [Army Materials and Mechanics Research Center] Newport, RI *(Army Materials and Mechanics Research Center, Arsenal Street, DRXMR-SM, Watertown, MA 02172 - (617) 923-5259)*

1-4 International Symposium on Aerodynamics and Acoustics of Propellers, Toronto, Canada *(L.H. Ohman, High Speed Aerodynamics Lab., N.R.C., Montreal Rd., Ottawa, Ontario K1A 0R6, Canada)*

1-7 International School of Ultrasonology, Erice, Italy *(CCSEM, 91016 Erice-Trapani, Sicily, Italy)*

7-11 10th Design Automation Conference and 18th Mechanisms Conference [ASME] Cambridge, MA *(Prof. Panos Papalambros, Mechanical Engineering and Applied Mechanics, The University of Michigan, Ann Arbor, MI 48109 - (313) 763-1046)*

7-12 Design and Production Engineering Technical Conferences [ASME] Cambridge, MA *(ASME Hqs.)*

9-11 *13th Space Simulation Conference* [IES, AIAA, ASTM, NASA] Orlando, FL *(Institute of Environmental Sciences, 940 E. Northwest Hwy., Mt. Prospect, IL 60056 - (312) 255-1561)*

9-12 Acoustical Society of America, Fall Meeting [ASA] Minneapolis, MN *(ASA Hqs.)*

15-18 Aerospace Congress and Exposition [SAE] Long Beach, CA *(SAE Hqs.)*

17-19 Stapp Car Crash Conference [SAE] Chicago, IL *(SAE Hqs.)*

22-24 ASME/ASLE Lubrication Conference [ASME/ASLE] San Diego, CA *(ASLE Hqs.)*

22-25 Symposium on Advances and Trends in Structures and Dynamics [George Washington University and NASA Langley Research Center] Washington, DC *(Prof. Ahmed K. Noor, Mail Stop 246, GWU-NASA Langley Research Center, Hampton, VA 23665 - (804) 865-2897)*

23-25 55th Shock and Vibration Symposium [Shock and Vibration Information Center, Washington, DC] Dayton, OH *(Dr. J. Gordan Showalter, Acting Director, SVIC, Naval Res. Lab., Code 5804, Washington, DC 20375 - (202) 767-2220)*

## NOVEMBER 1984

14-16 Aeronautical Acoustics, Compiegne, France *(J.F. de Belleval, U.T.C., P.O. Box 233, 60206 Compiegne Cedex, France)*

## DECEMBER 1984

3-5 International Conference on Noise Control Engineering [International Institute of Noise Control Engineering] Honolulu, Hawaii *(INTER-NOISE 84 Secretariat, Noise Control Foundation, P.O. Box 3469, Arlington Branch, Poughkeepsie, NY 12603 - (914) 462-6719)*

3-6 Truck and Bus Meeting and Exposition [SAE] Detroit, MI *(SAE Hqs.)*

9-13 ASME Winter Annual Meeting [ASME] New Orleans, LA *(ASME Hqs.)*

13-14 Underwater Acoustic Calibration and Measurements, Bracknell, Berks. UK *(L. Lipscombe, db Instrumentation Ltd., Eastern Road, Aldershot, England)*

28-31 International Conference on Applied Numerical Modeling/Computational Mechanics, Tainan, Taiwan, ROC *(S.Y. Wang, Engineering, University of Mississippi, University, MS 38677)*

## JANUARY 1985

22-24 Annual Reliability and Maintainability Symp. [IES] Philadelphia, PA *(IES Hqs.)*

29-1 International Conference on Nondestructive Evaluation in Nuclear Industry, Grenoble, France *(J.P. Launay, COFREND, 32 Boulevard de la Chapelle, 75880 Paris Cedex 18, France)*

## FEBRUARY 1985

25-Mar 1 International Congress and Exposition [SAE] Detroit, MI *(SAE Hqs.)*

## MARCH 1985

18-21 30th Intl. Gas Turbine Conf. and Exhibit [ASME] Houston, TX *(Intl. Gas Turbine Ctr., Gas Turbine Div., ASME, 4250 Perimeter Park South, Suite 108, Atlanta, GA 30341 - (404) 451-1905)*

## CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics
1633 Broadway
New York, NY 10019

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASLE: American Society of Lubrication Engineers
838 Busse Highway
Park Ridge, IL 60068

ASME: American Society of Mechanical Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

ICF: International Congress on Fracture
Tohoku University
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IMechE: Institution of Mechanical Engineers
1 Birdcage Walk, Westminster,
London SW1, UK

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
67 Alexander Dr.
Research Triangle Park, NC 27709

SAE: Society of Automotive Engineers
400 Commonwealth Dr.
Warrendale, PA 15096

SEE: Society of Environmental Engineers
Owles Hall, Buntingford, Hertz.
SG9 9PL, England

SESA: Society for Experimental Stress Analysis
14 Fairfield Dr.
Brookfield Center, CT 06805

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Laboratory
Code 5804
Washington, D.C. 20375

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## PUBLICATION POLICY

Unsolicited articles are accepted for publication in the **Shock and Vibration Digest**. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

> Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].
>
> Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

The format and style for the list of References at the end of the article are as follows:

- each citation number as it appears in text (not in alphabetical order)
- last name of author/editor followed by initials or first name
- titles of articles within quotations, titles of books underlined
- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
- volume, issue number, and pages for journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Platzer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Dev. (1962).
4. Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., 27 (3), pp 220-231 (1948).
5. Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).
6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).
7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 24 (1), pp 65-66 (1957).

Articles for the DIGEST will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the DIGEST. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 3000 to 4000 words in length. For additional information on topics and editorial policies, please contact:

Milda Z. Tamulionis
Research Editor
Vibration Institute
101 W. 55th Street, Suite 206
Clarendon Hills, Illinois 60514